SKYWARN *Advanced* Training

Gerald Satterwhite
Meteorologist

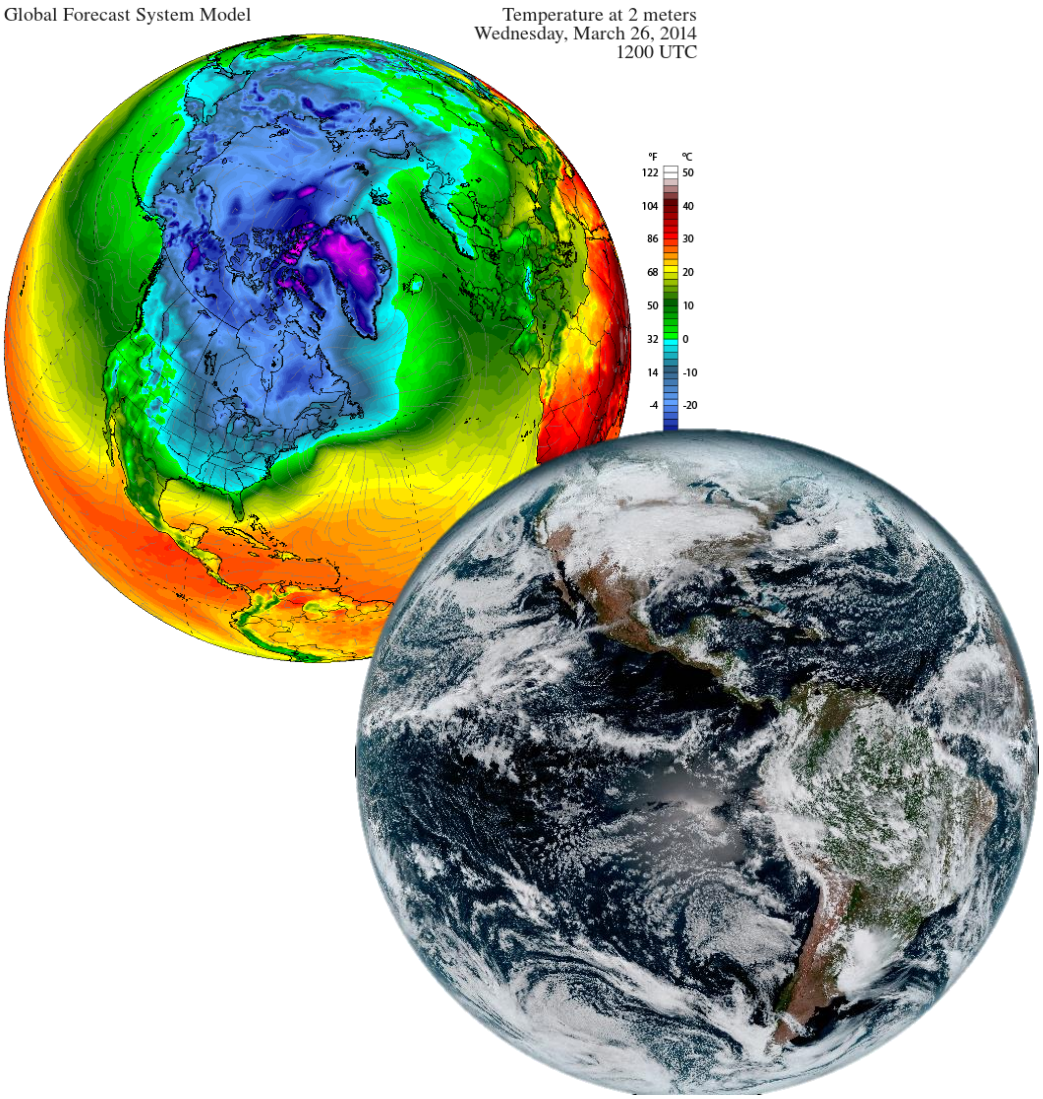
U.S. Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)
National Weather Service (NWS) – Calera, AL

Welcome to Advanced Spotter Training

We'll take an in-depth look at:

- Development processes and ingredients
- Severe thunderstorm forecasting
- Inspecting radar and satellite imagery

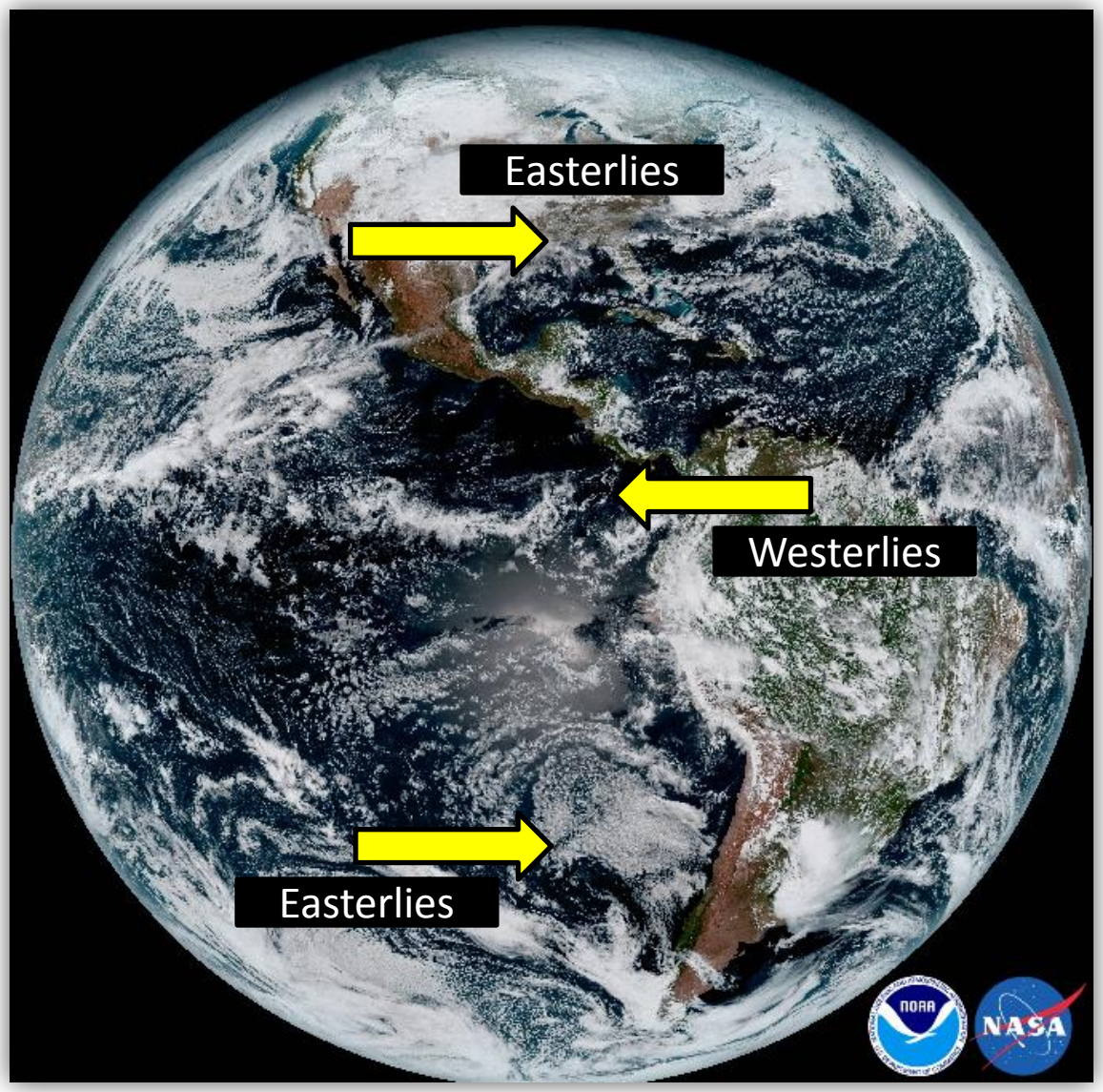
The Atmosphere

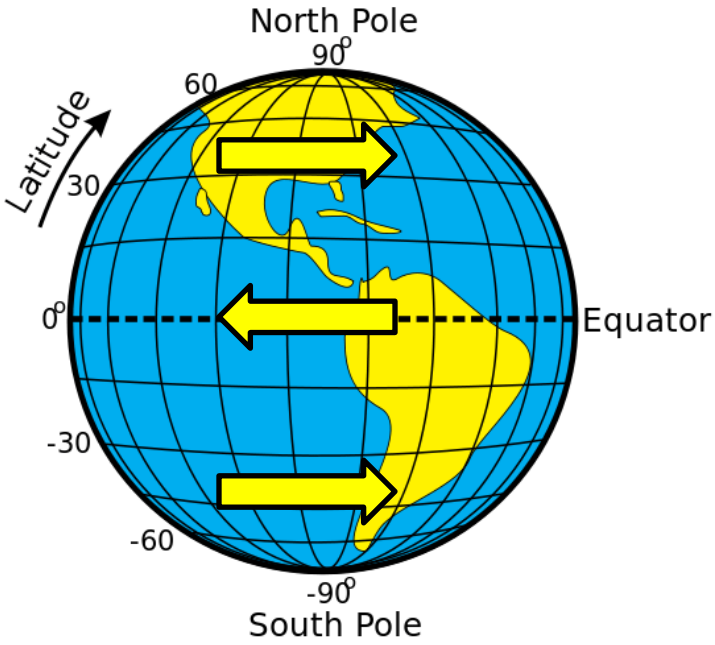


Large to Small Scale

- Global (Largest)
- Synoptic (Large)
- Mesoscale (Small)

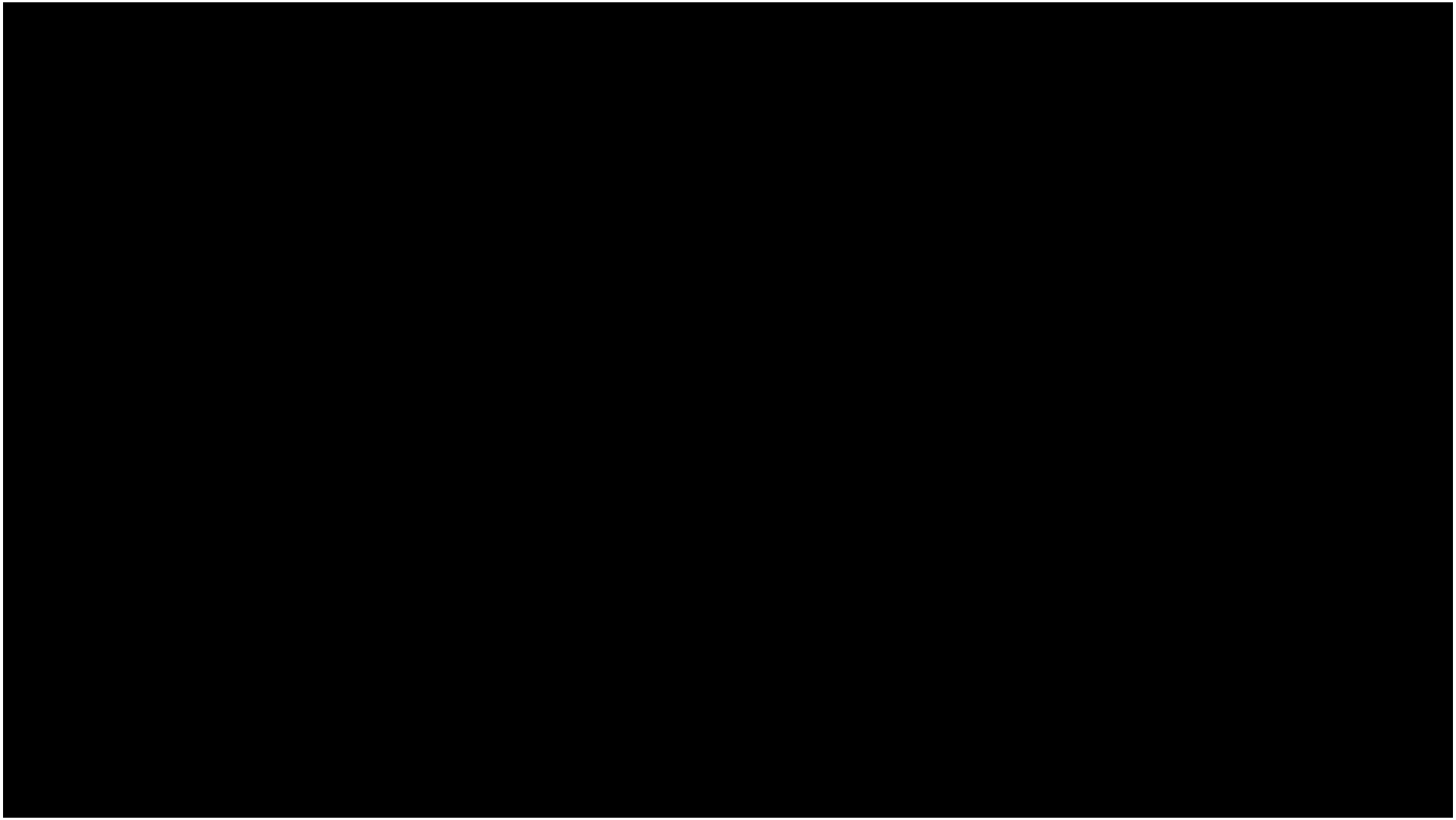
Global Weather Patterns



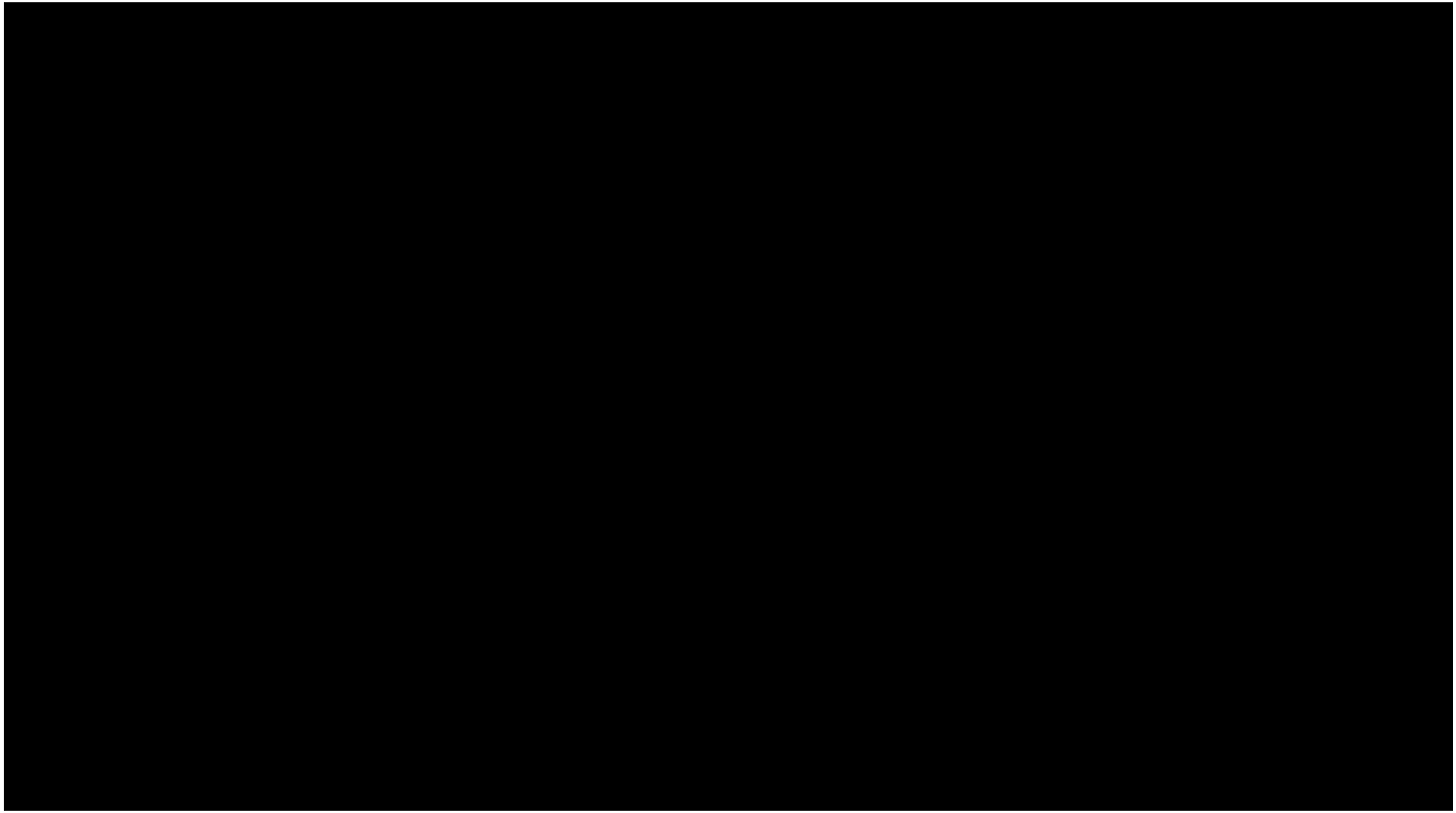


The sun drives the weather!

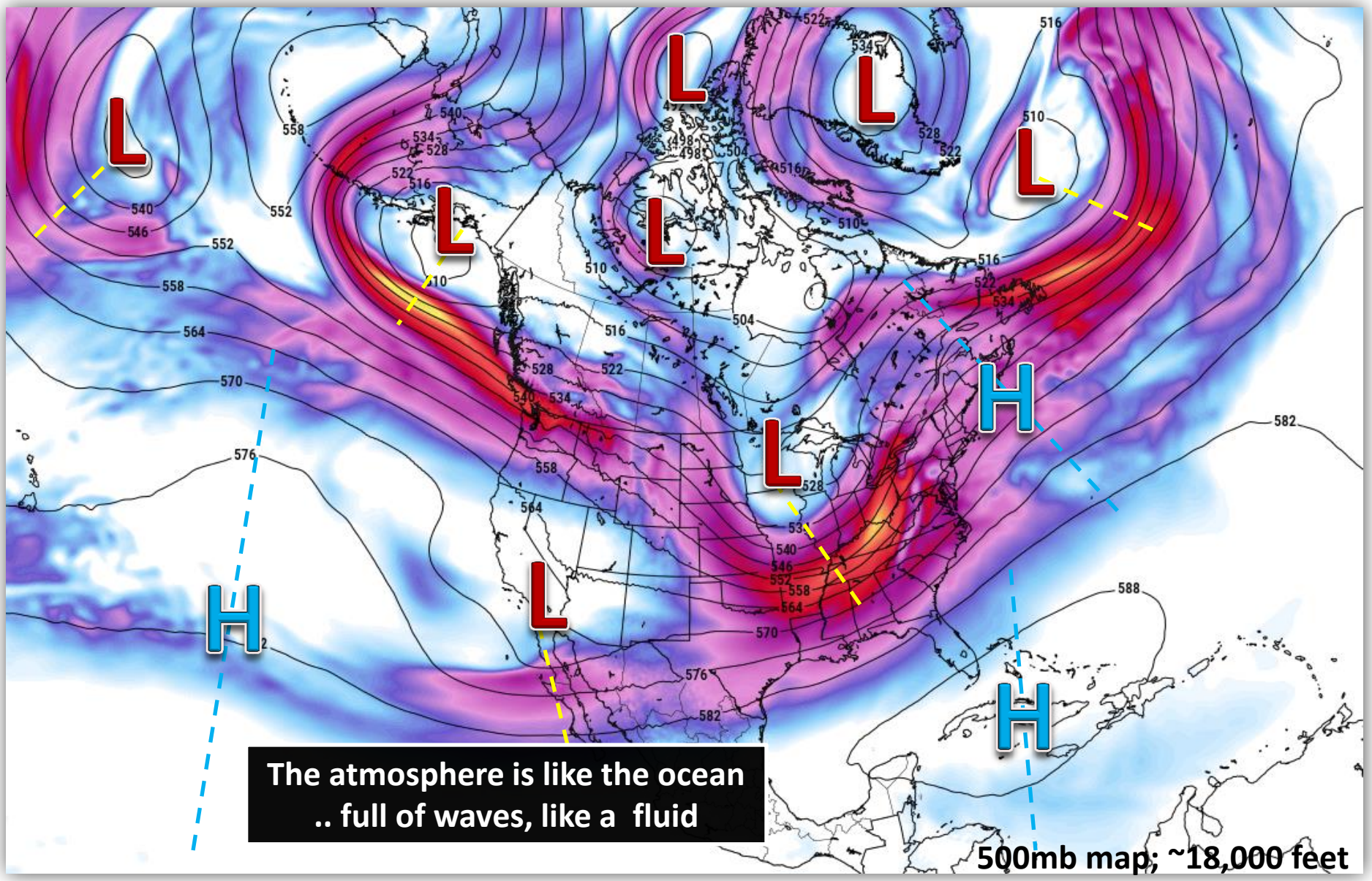
GOES-16 Full Disk Animation



GOES-16 Full Disk Channels (16)

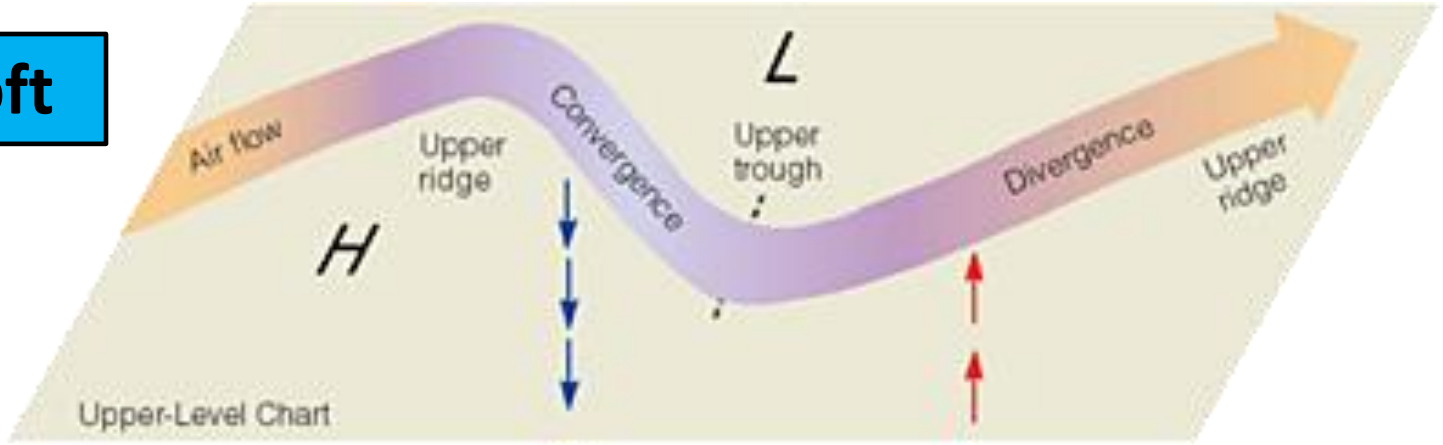


Synoptic Weather Patterns

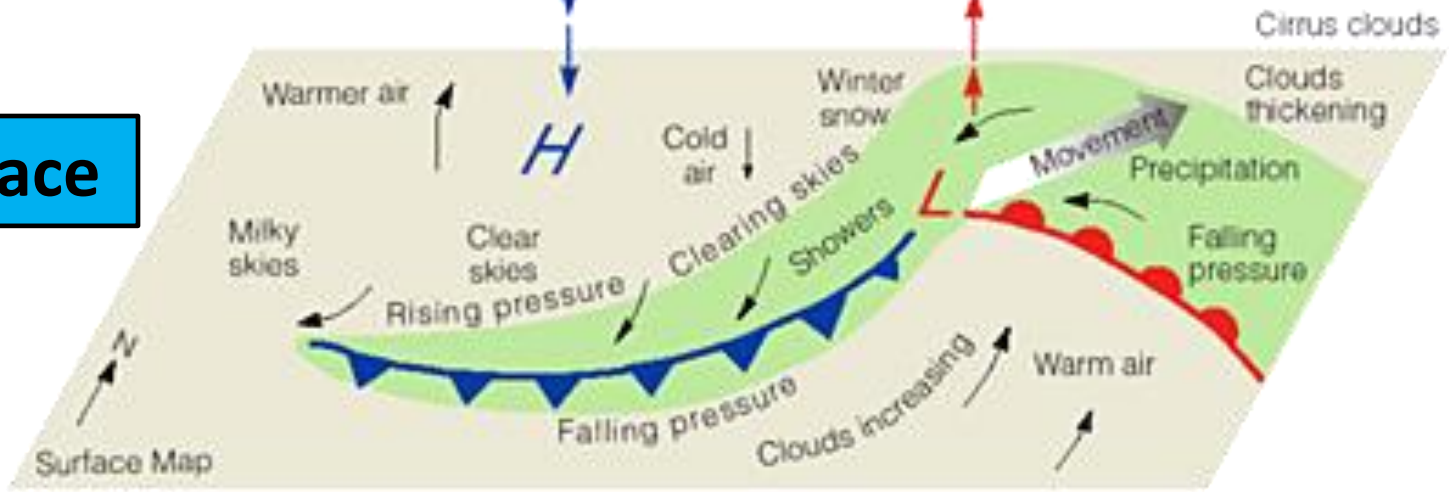


Synoptic Weather Patterns: Top-down

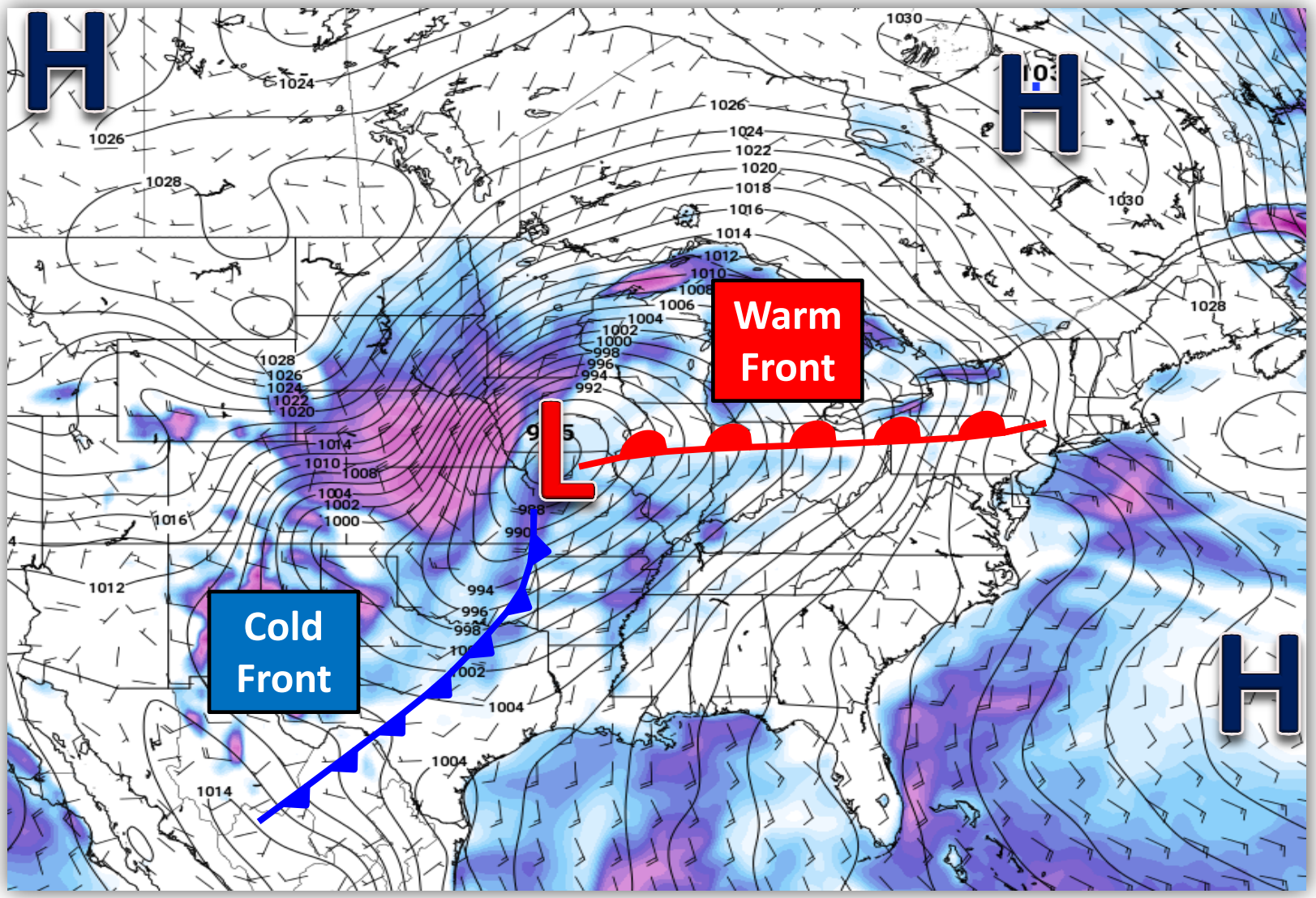
Aloft



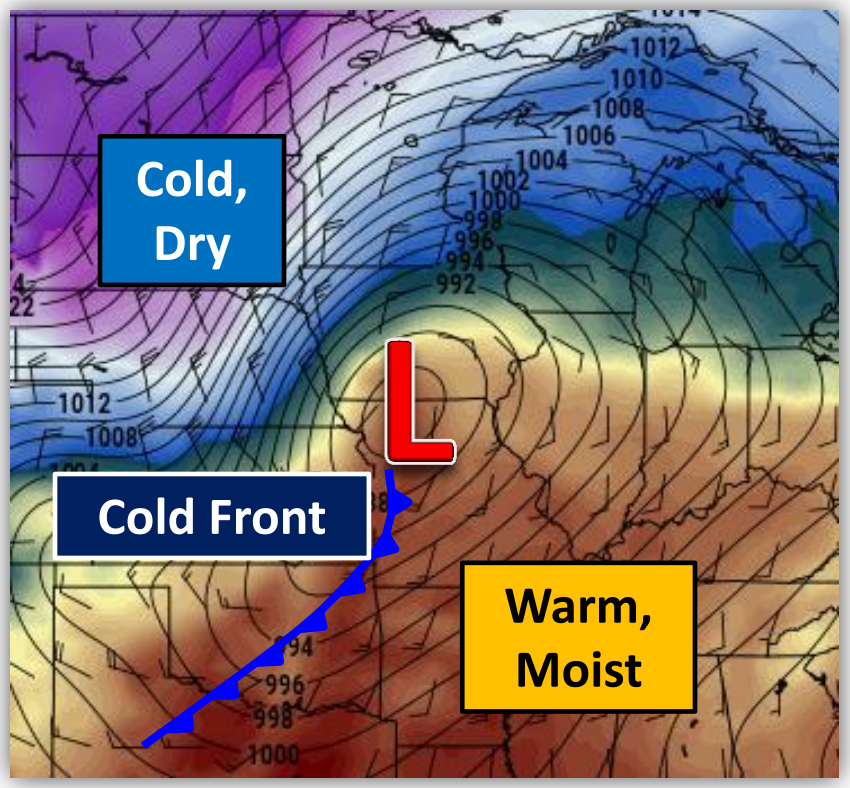
Surface

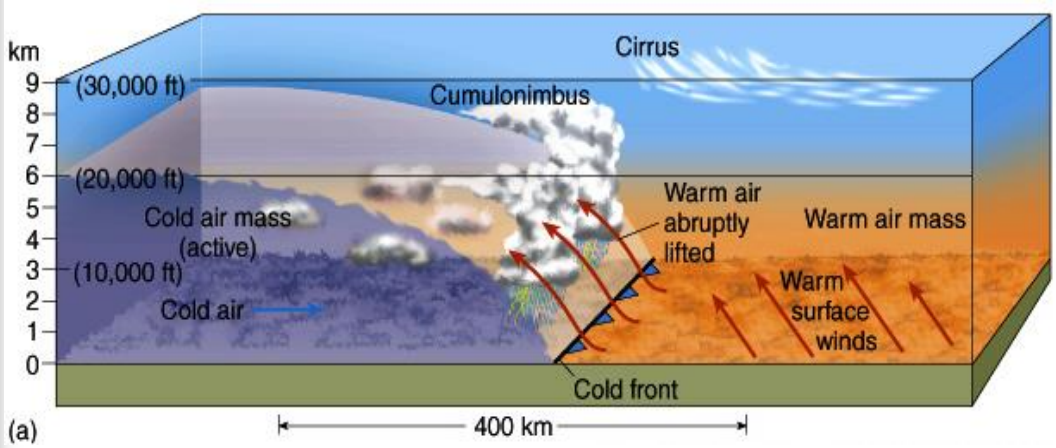


Synoptic Weather Pattern: Low Pressure System



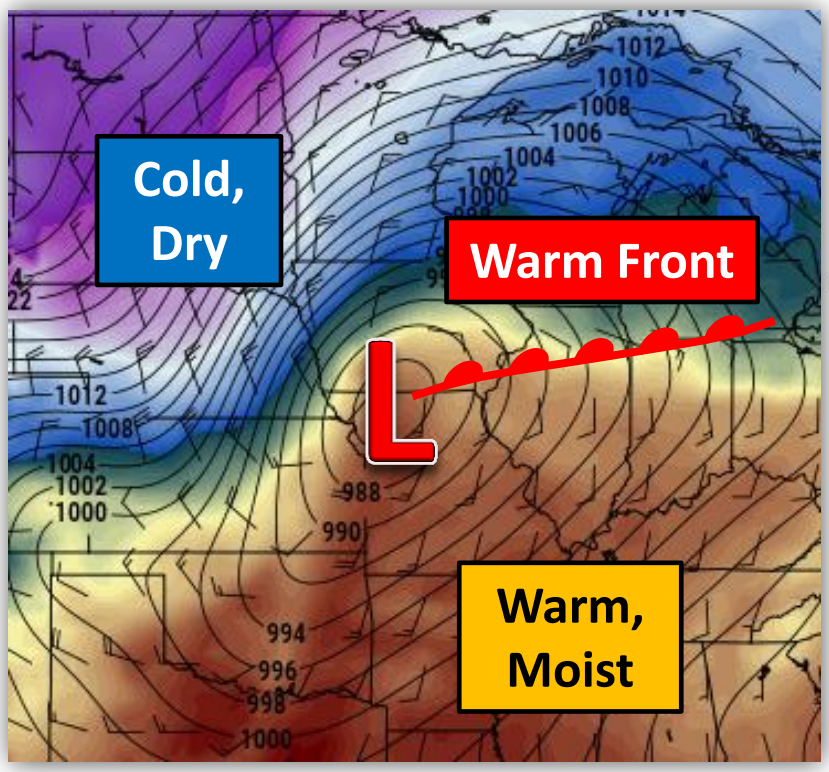
Synoptic Weather Pattern: Low Pressure System, Cold Front

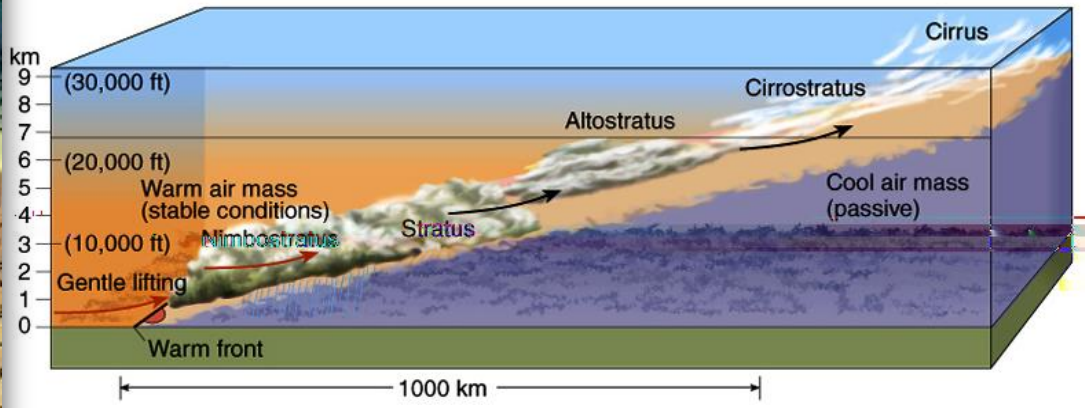




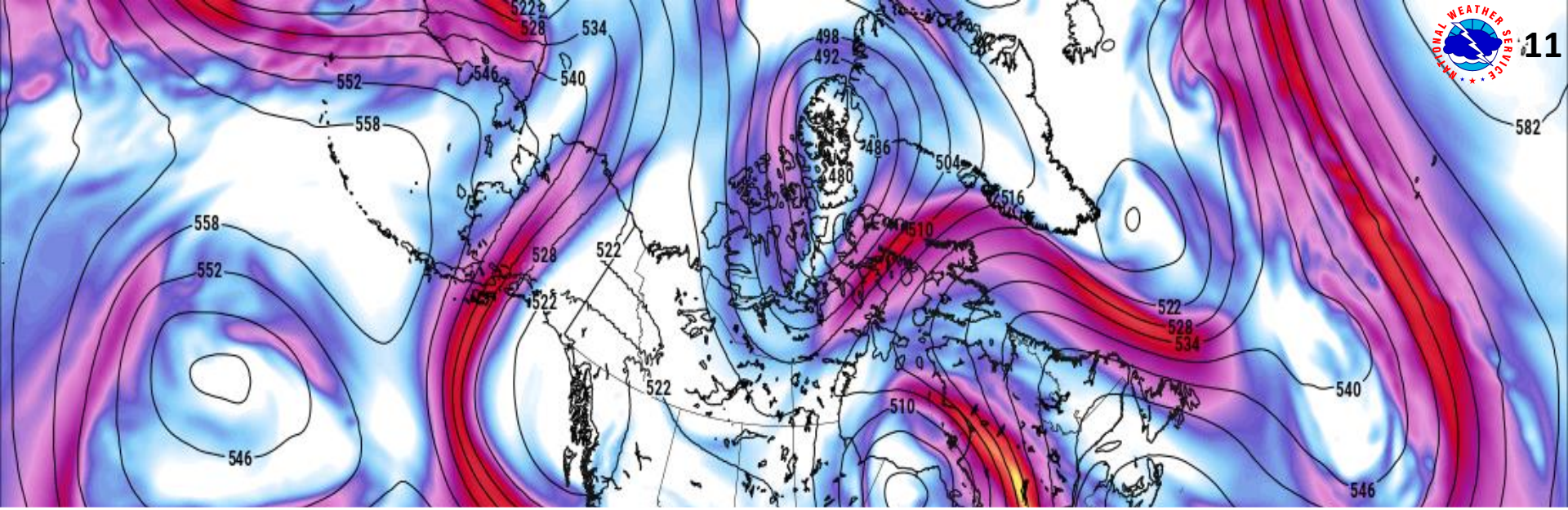
Cold front definition: A zone separating two air masses, of which the cooler, denser mass is advancing and replacing the warmer

Synoptic Weather Pattern: Low Pressure System, Warm Front

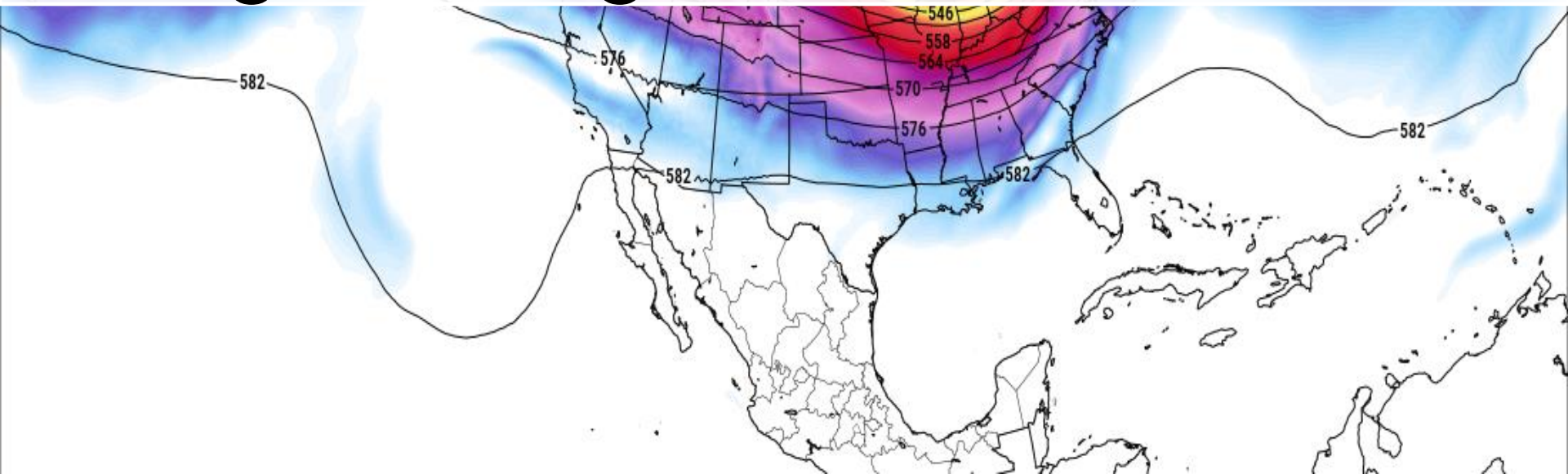




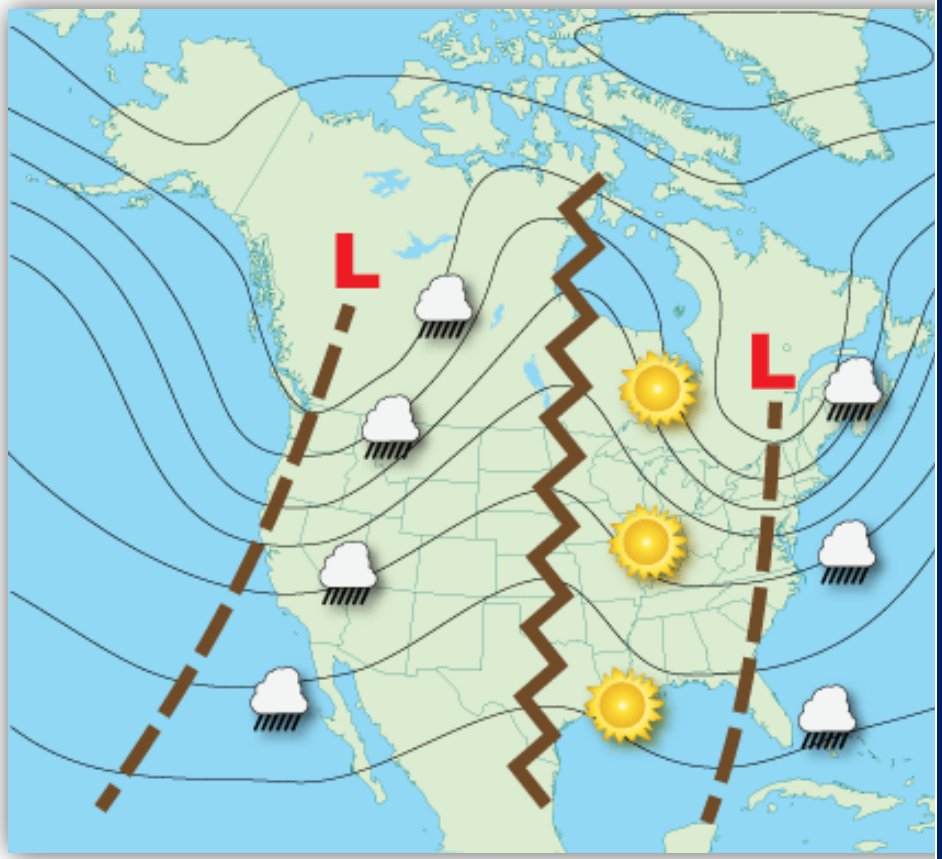
Warm front definition: A transition zone between a mass of warm air and the colder air it is replacing



Synoptic Weather Pattern Types: Ridges, Troughs, and Cut-off Lows

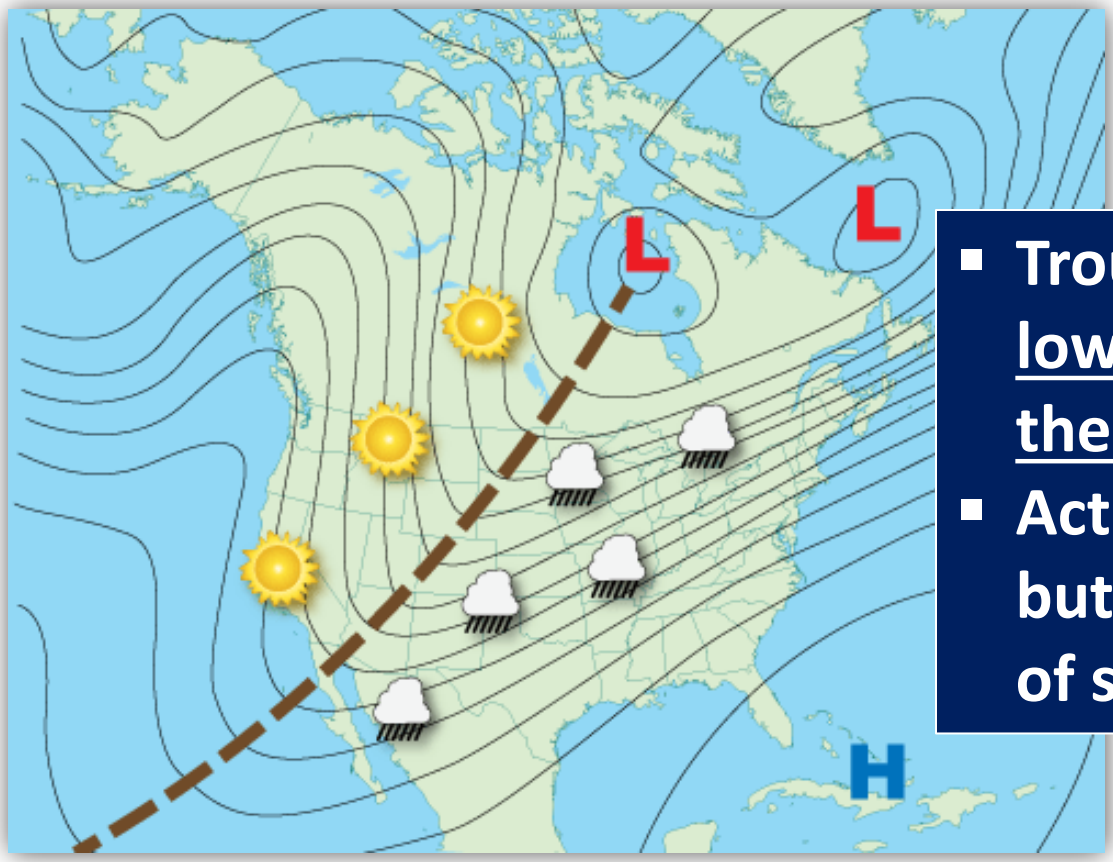


Neutrally-Tilted Troughs



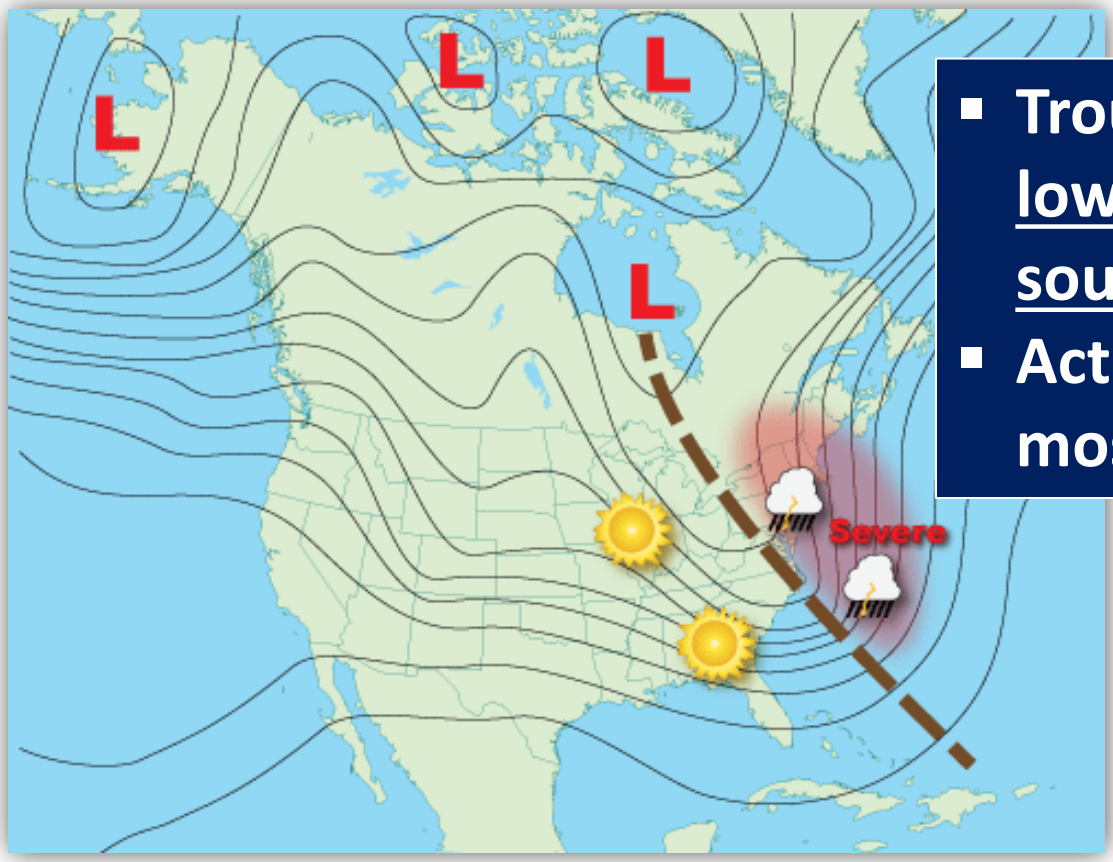
- Trough axis extends from the <u>lowest pressure north to south</u>
- The most common weather pattern
- Active weather occurs between the trough and downwind (eastward) ridge
- Fair weather occurs within and between the downwind trough

Positively-Tilted Troughs



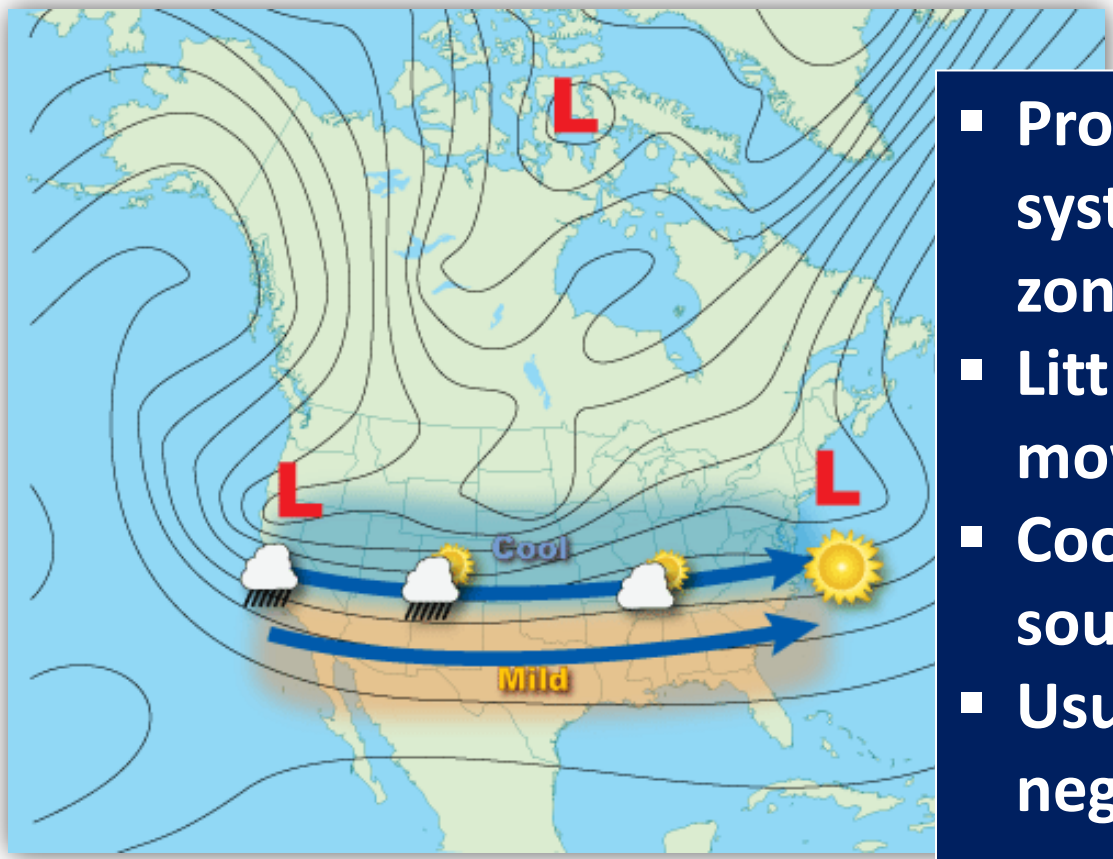
- Trough axis extends from the <u>lowest pressure northeast to the southwest</u>
- Active weather can occur, but not too much in the way of severe storms

Negatively-Tilted Troughs



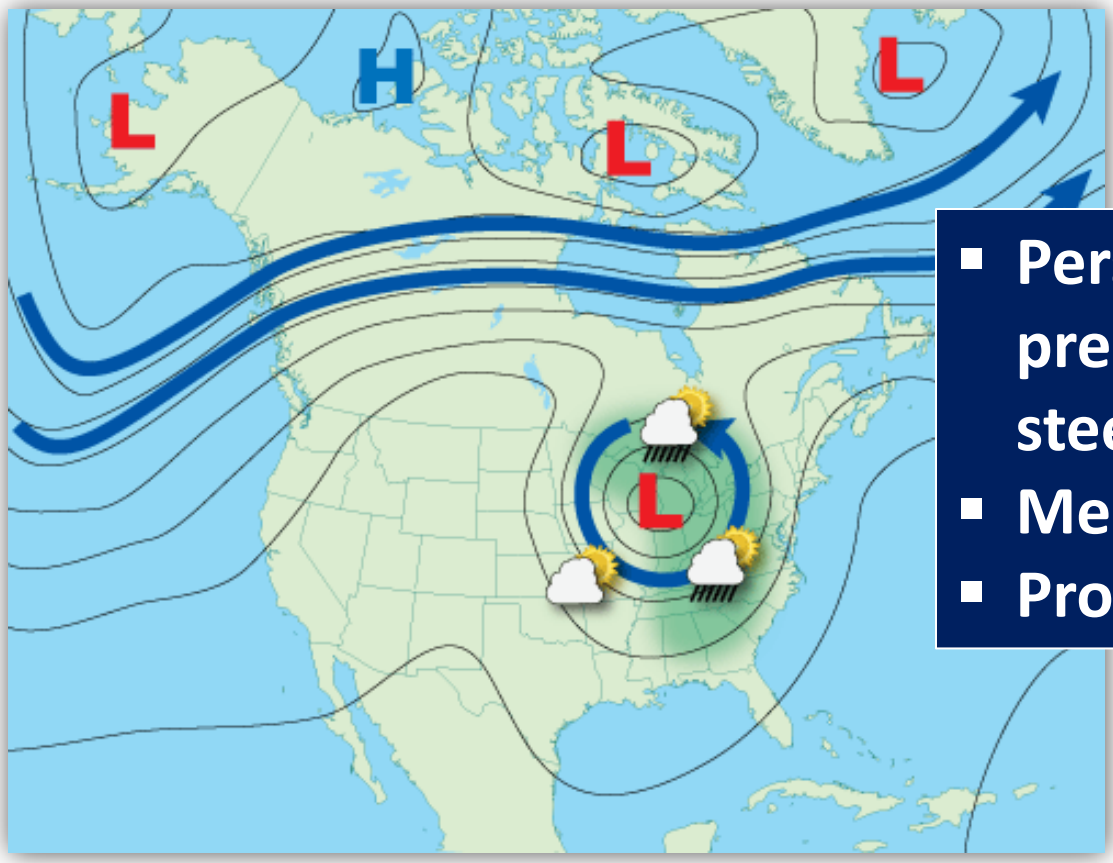
- Trough axis extends from the lowest pressure northwest to southeast
- Active weather with the most severe potential

Zonal (west to east) Flow



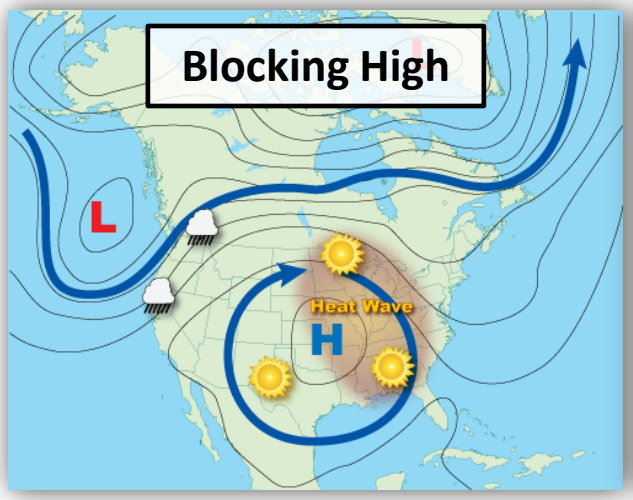
- Progressive motion of storm systems west to east along zonal axis
- Little north or south movement
- Cooler air north, warmer south
- Usually a positively- and negatively-tilted trough at each end

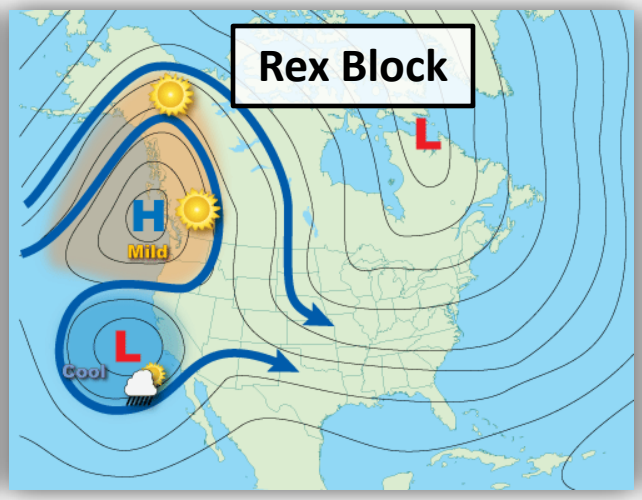
Cut-off Low

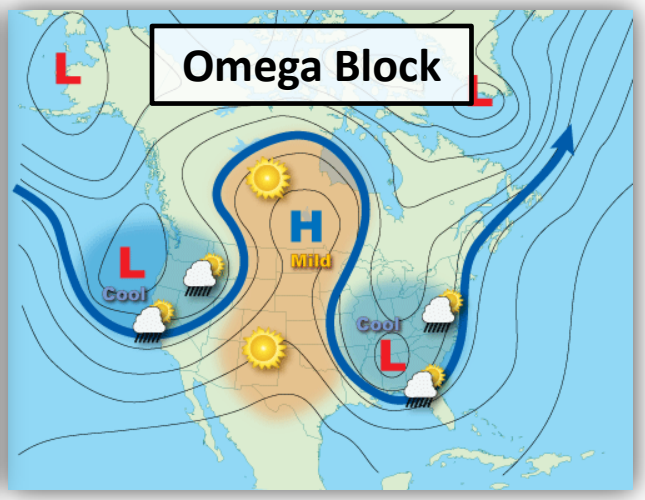


- Persistent area of low pressure removed from the steering flow
- Meander for several days
- Produce unsettled weather

Blocking Patterns

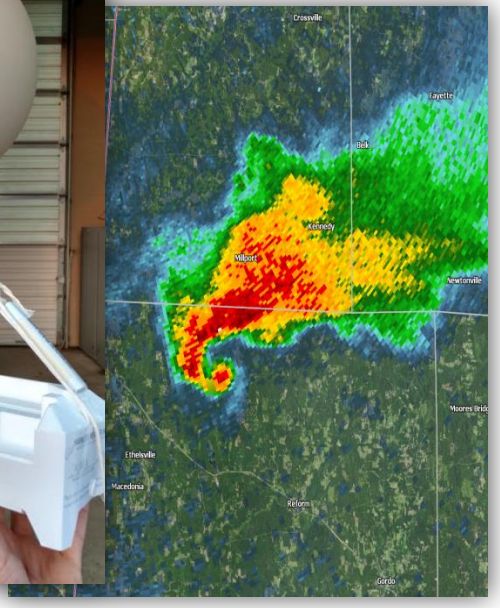






- When weather systems set up in a way that prevents others from moving through
- Weather systems are forced to go around the block
- Result long spans of persistent weather conditions for any given area

The Storm System is Arriving: What is the NWS Up To?

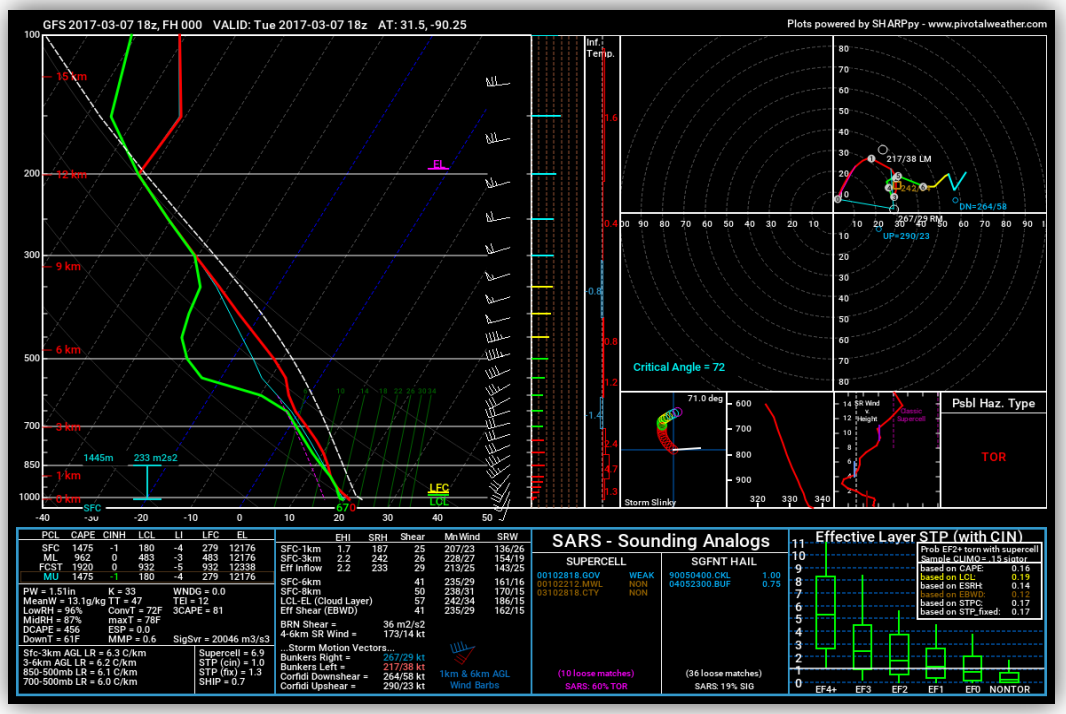


Protect Life and Property

Help you make informed decisions

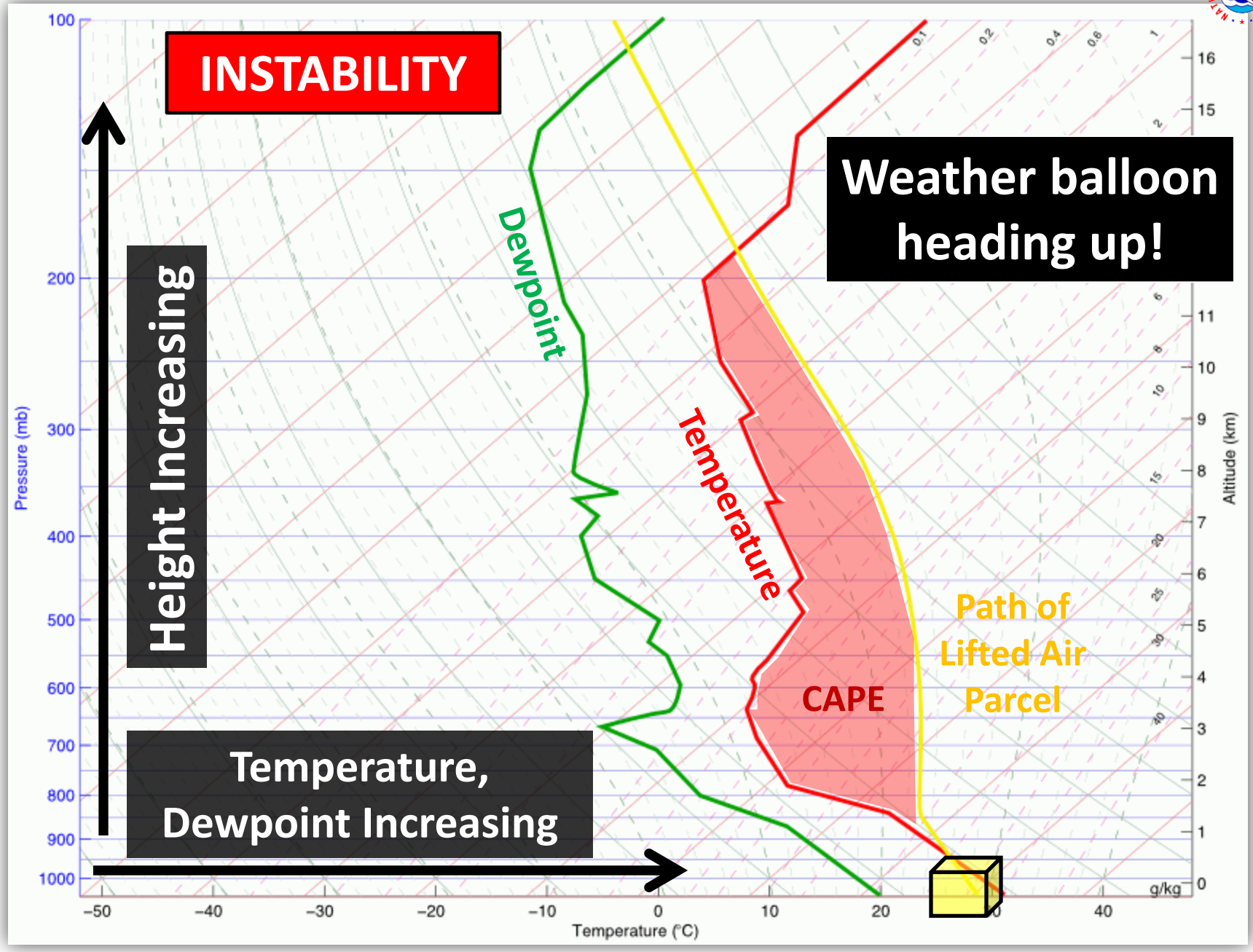
Building a Weather-Ready Nation

What's In a Sounding?

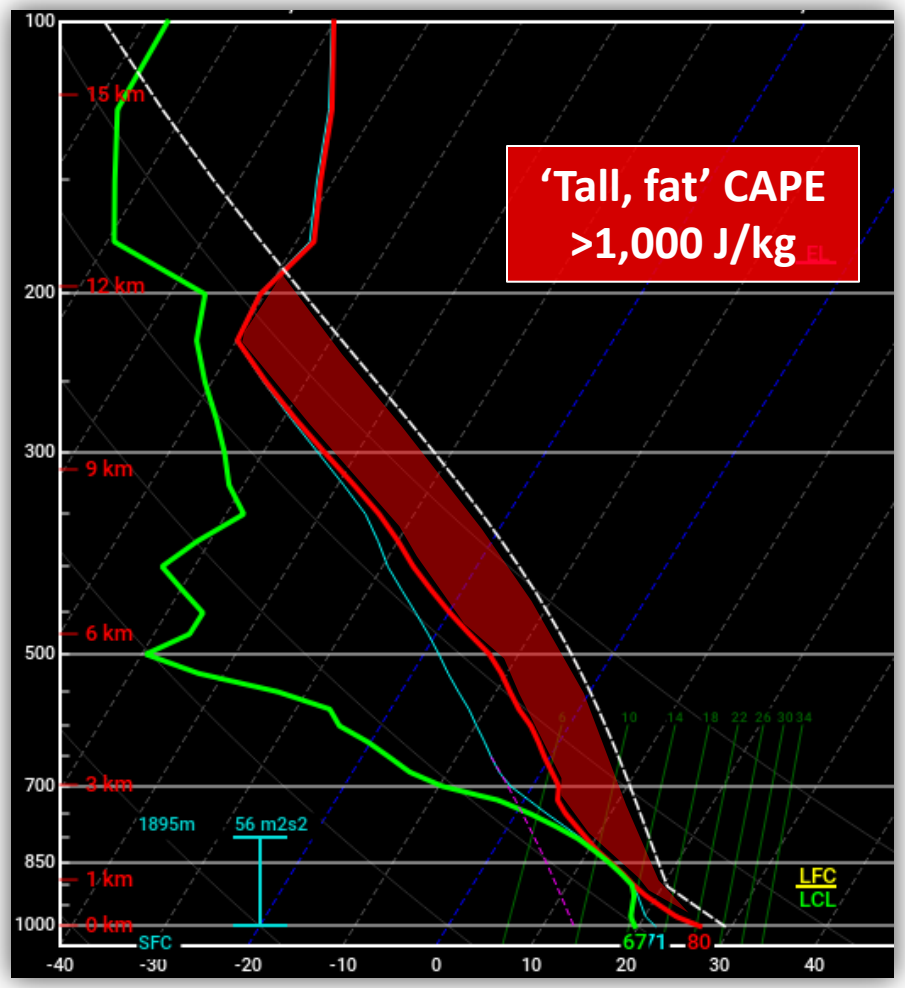


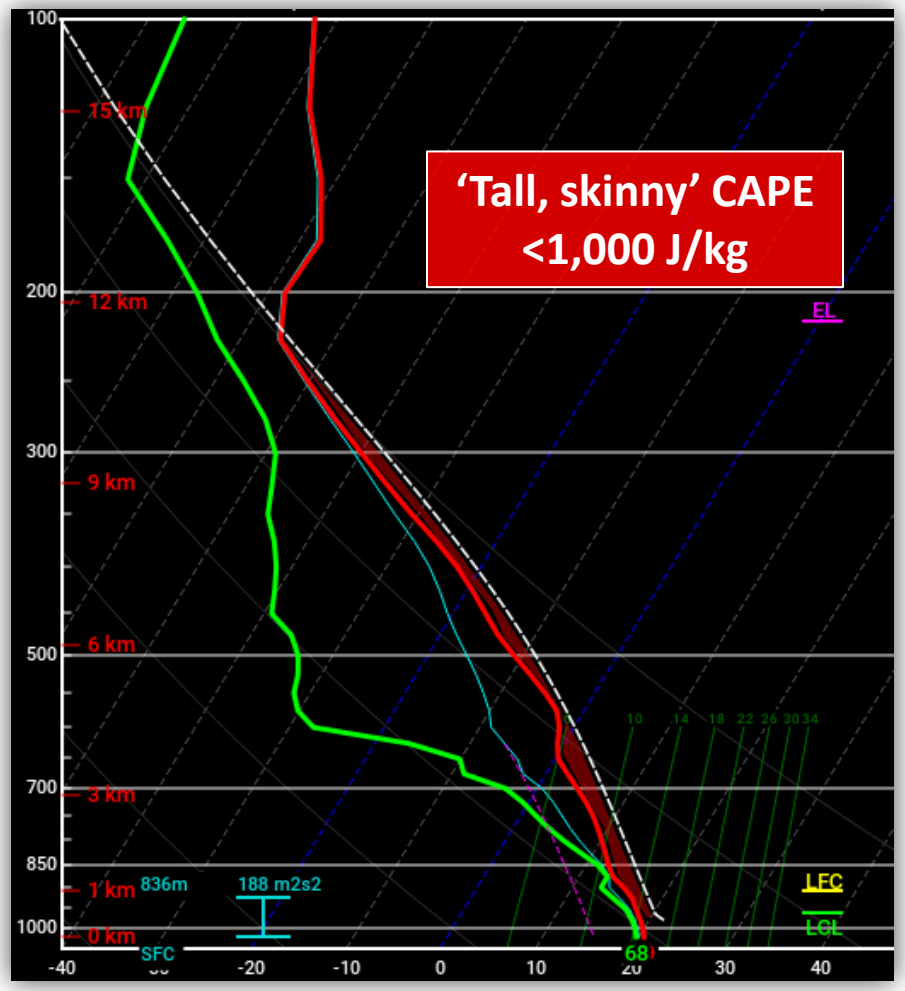
- SRH (storm-relative helicity): measure of potential for rotating updrafts in right-moving storms
- 0-1km; 0-3km shear magnitude
- Bulk shear: Measure of deep-layer shear
- Wind vector from surface-850mb-500mb

- LCL (lifted condensation level): level at which a lifted parcel becomes saturated
- LFC (level of free convection): Level at which a parcel freely accelerates upward to equilibrium level
- EL (equilibrium level): Level at which a lifted parcel is no longer buoyant
- Lapse rates: rate of temperature change with height
- CAPE (convective available potential energy): measure of instability
- DCAPE: measure of potential strength of rain-cooled downdrafts
- CIN (convective inhibition): measure of stability
- LI (lifted index): temperature difference between 500mb temp and lifted parcel temp at 500mb

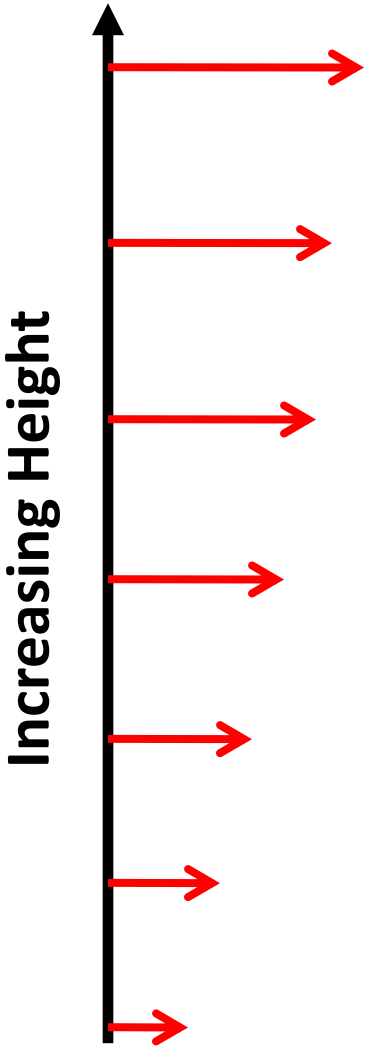

INSTABILITY
Weather balloon heading up!
Height Increasing
Temperature, Dewpoint Increasing
Dewpoint
Temperature
CAPE
Path of Lifted Air Parcel
Pressure (mb)
Altitude (km)
Temperature (°C)
g/kg
100
200
300
400
500
600
700
800
900
1000
−50
−40
−30
−20
−10
0
10
20
40

Weak vs. Strong CAPE (Convective Available Potential Energy)

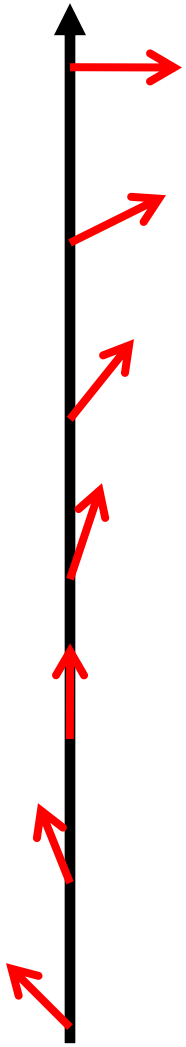




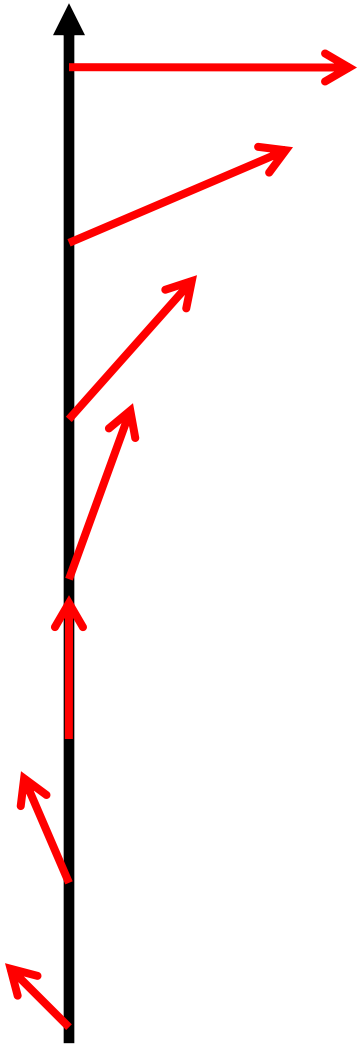
Wind Shear



Change in wind speed with height

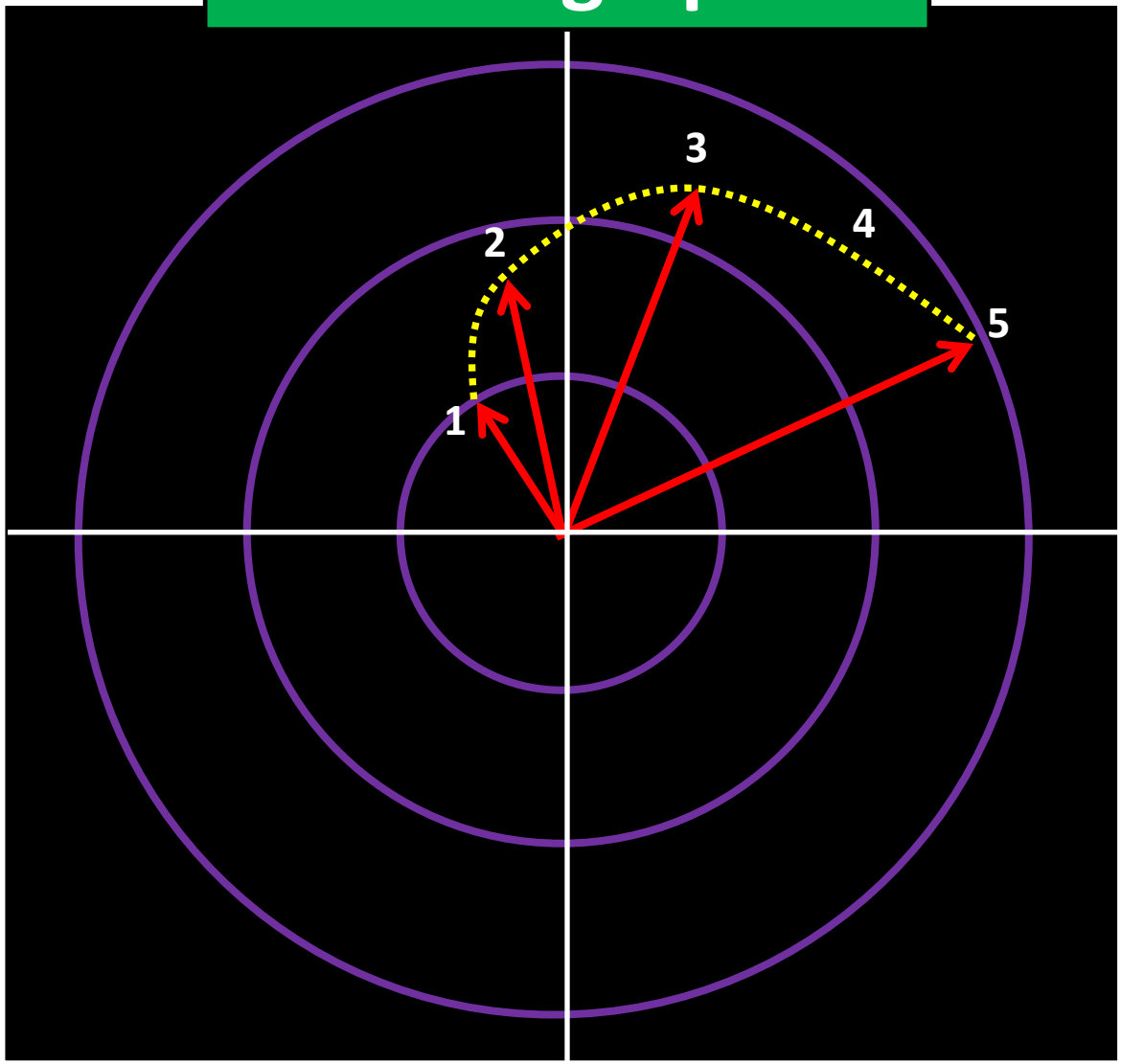


Change in wind direction with height

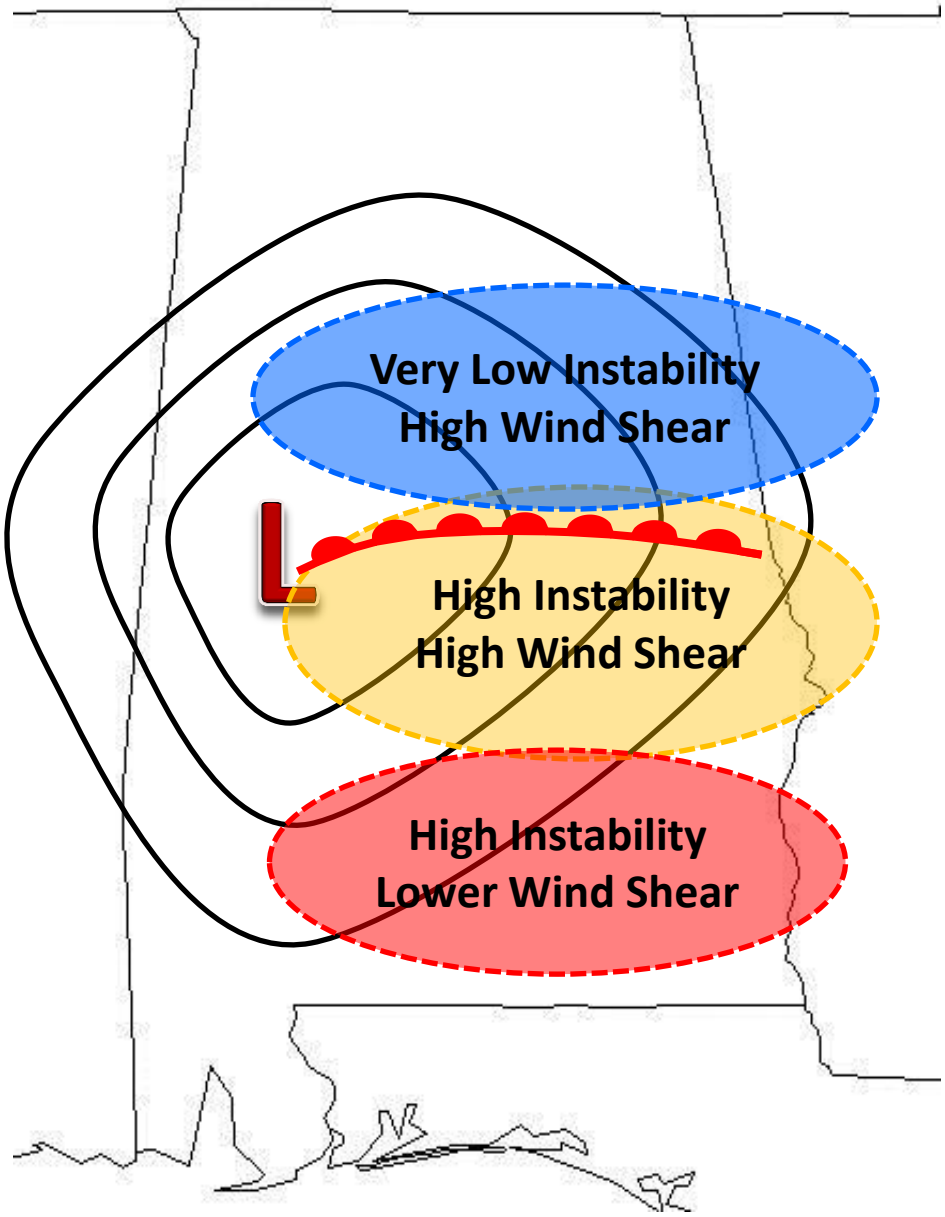


Change in wind speed and direction with height

Hodograph

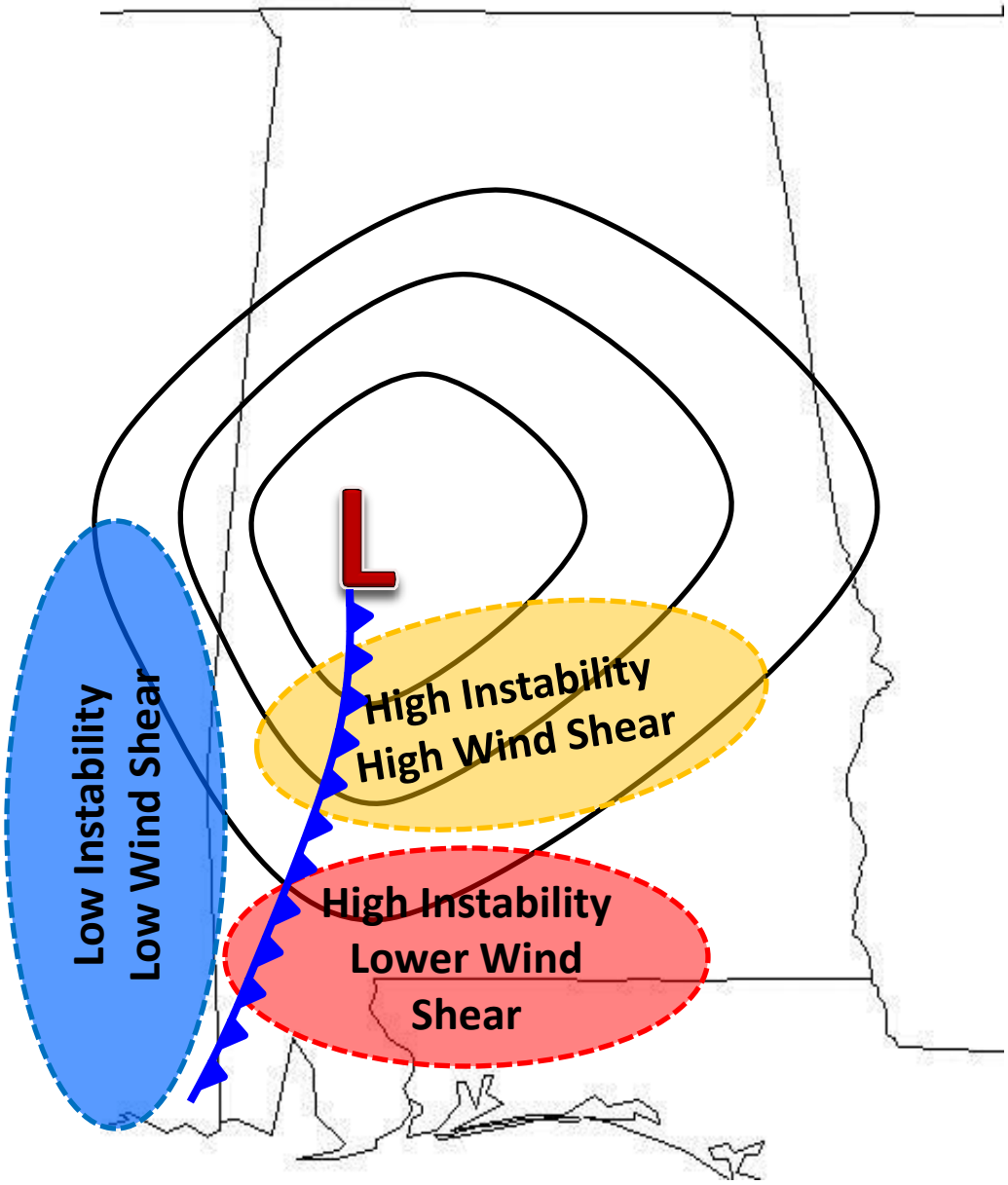


- Wind shear is typically calculated in terms of speed and direction. The change in these is known as helicity or storm-relative helicity
- Helicity is measured at several heights. Helps determine what type of storm is likely to form/severe hazards



Warm Front

- Typically have a distinct wind shift from the south to the east across the front
- Increasing instability south of the warm front, lower north
- Wind shear highest near and north of the warm front

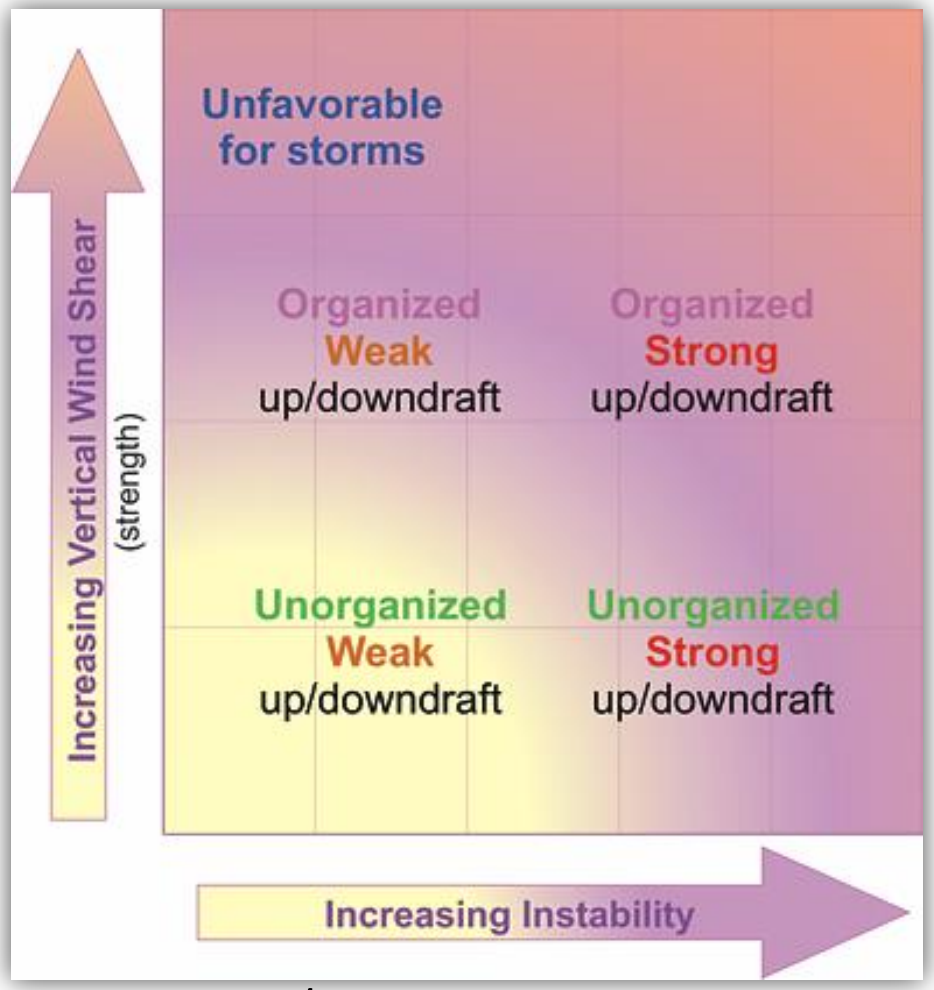


Cold Front

- Typically have an abrupt wind shift from the south to northwest across the front
- Unstable ahead of front, increasingly stable behind
- Wind shear highest ahead of front, lowest behind

Recall: Thunderstorm Ingredients

- Lift
  - Cold front
  - Warm front
  - Gust front, outflow boundary
  - Terrain (upslope flow)
  - Surface heating
- Moisture
- Instability



*Wind Shear helps with thunderstorm organization/longevity and severity

Severe Thunderstorm Parameters

Storm Type? Severity?

Vertical Wind Shear & SRH

- 0-6 km bulk shear > 40 kts – supercells
- 0-6 km bulk shear 20-35 kts – organized multicells
- 0-6 km bulk shear < 10-20 kts – disorganized multicells
- 0-8 km bulk shear > 52 kts – long-lived supercells
- 0-3 km bulk shear > 30-40 kts – bowing thunderstorms

SRH

- 0-3 km SRH > 150 $m^2 s^{-2}$ = updraft rotation becomes more likely
- 0-3 km SRH > 300-400 $m^2 s^{-2}$ = rotating updrafts and supercell development likely

BOTH

- 0-6 km shear < 35 kts with 0-3 km SRH > 150 $m^2 s^{-2}$ – brief rotation but not persistent
- 0-6 km shear < 35 kts – any storm that acquires rotation will not persist for very long
- 0-6 km shear > 40 kts with 0-3 km SRH < 150 $m^2 s^{-2}$ – a supercell can still develop
- 0-6 km shear > 40 kts with 0-3 km SRH > 150 $m^2 s^{-2}$ – updraft rotation may be strong
- When 0-6 km shear is 30-40 kts (i.e., marginal), but the atmosphere is very unstable
- CAPE > 2500 J kg^{-1}, supercells can still form. This is especially true along low-level boundaries.

Large Hail

- -10 to -30° C layer is the hail growth zone; look for a large CAPE within -10 to -30° C layer
- Rotating updraft – the longer hail resides within hail growth zone, the greater the potential for large hail

Supercells & Hail

- Large boundary layer moisture
- 700-500 mb lapse rates > 7.0 C km^{-1}
- Moderate to large CAPE, including "fat" CAPE for rapid acceleration
- 0-6 km shear > 40-50 kts (includes speed and directional)
- 0-3 km SRH > 150-200 $m^2 s^{-2}$

Hodograph:

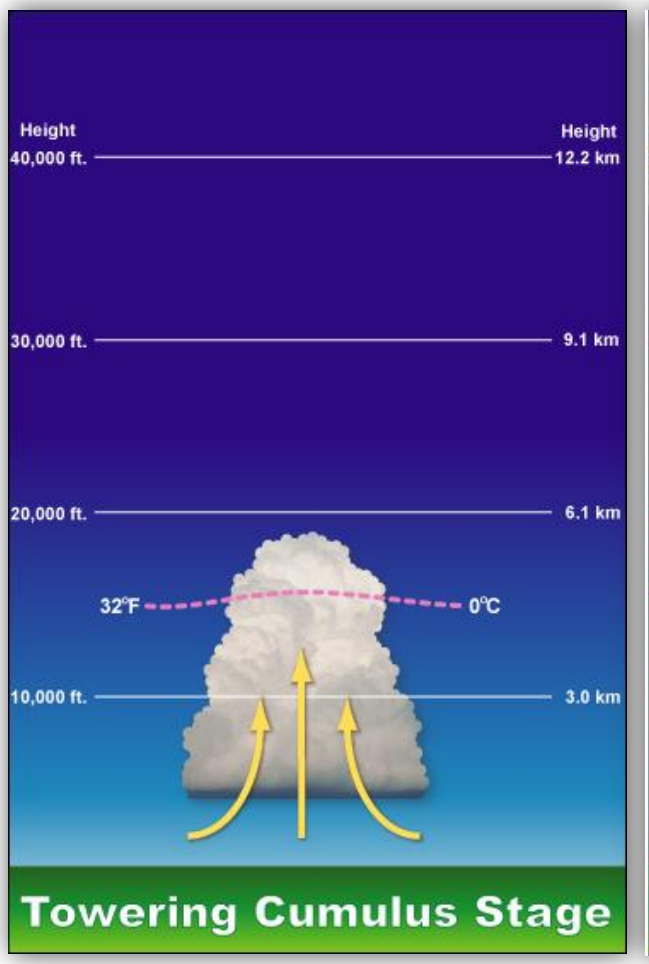
- The 0-1 km hodograph spike is relatively straight (no curvature). Above the spike, the hodograph then displays stronger turning and curvature.
- 0-1 km bulk shear > 20 kts
- 0-1 km SRH > 150-300 $m^2 s^{-2}$
- Boundary layer RH > 65%
- LCL heights ≤ 1000 m (3000 ft)
- Most of the 0-3 km SRH is concentrated in 0-1 km layer
- Low LCL heights (large boundary layer RH) favor warm RFDs and tornadogenesis
- High LCL heights (low boundary layer RH) favor cold RFDs and tornadogenesis-failure

Derechoes

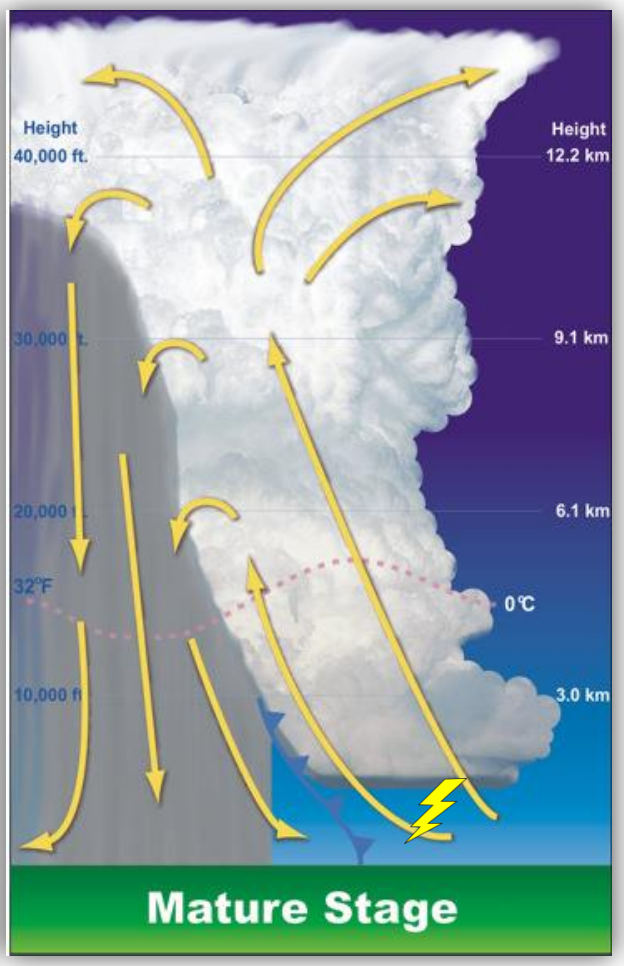
- Prolonged bow echo/damaging wind events; favored in environments with high to extreme instability; fast low to mid-level unidirectional flow
- 0-3 km bulk shear > 30 kts; 0-6 km bulk shear > 40 kts

Halftime!
10-minute Break

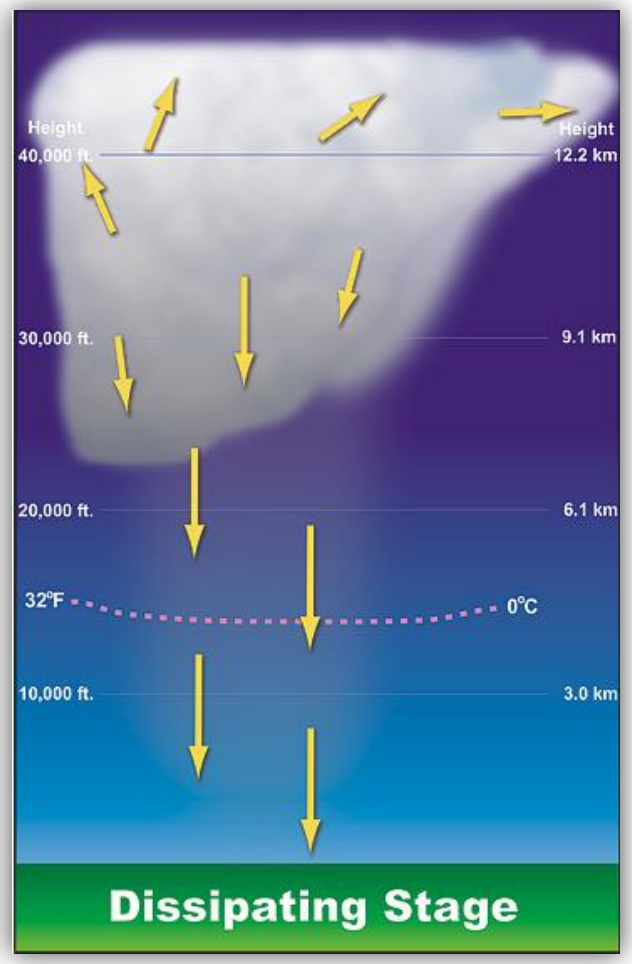
Thunderstorm Stages



- Updraft dominates
- Cumulus cloud grows vertically
-Up to ~20,000 feet tall

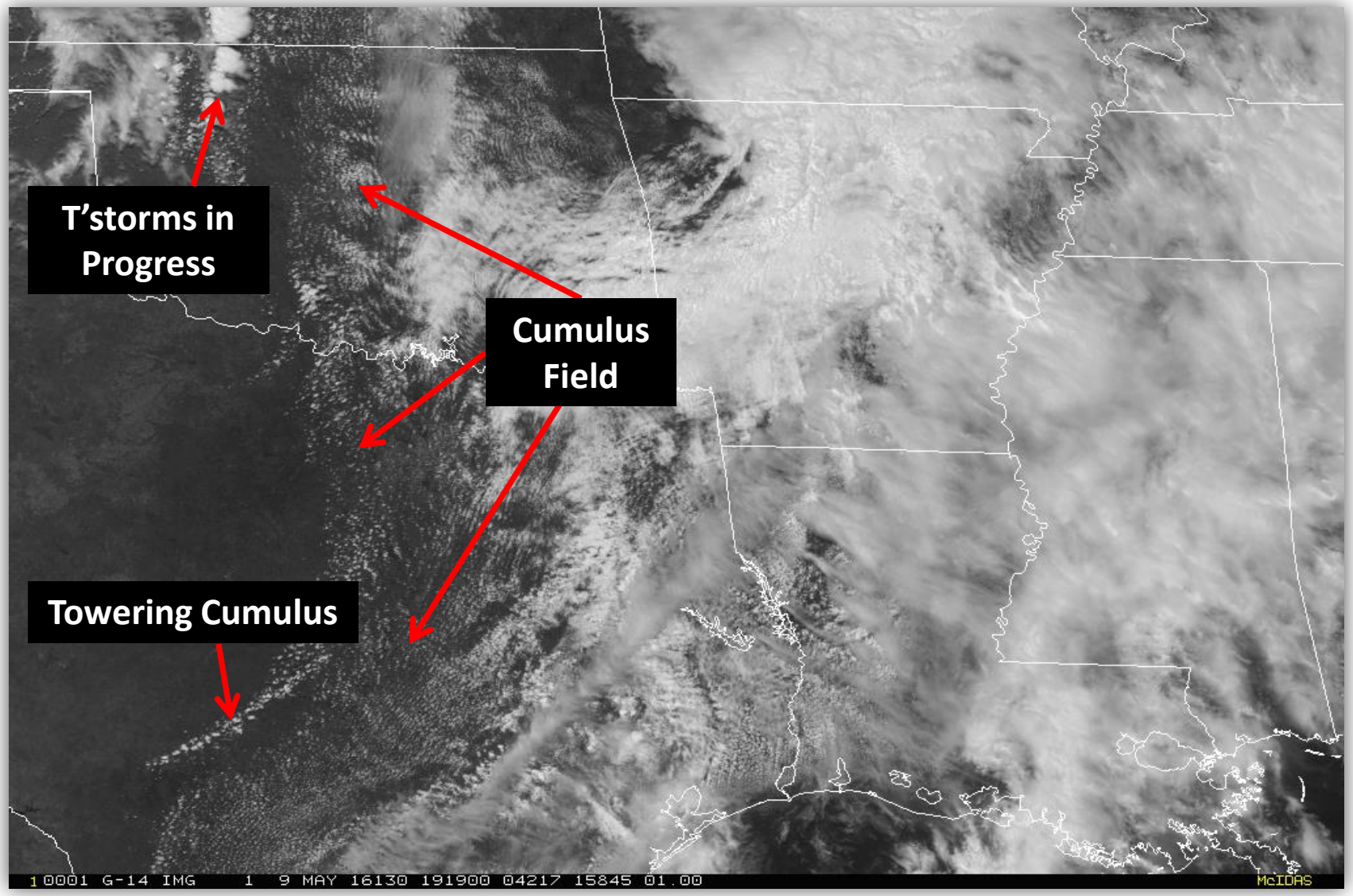


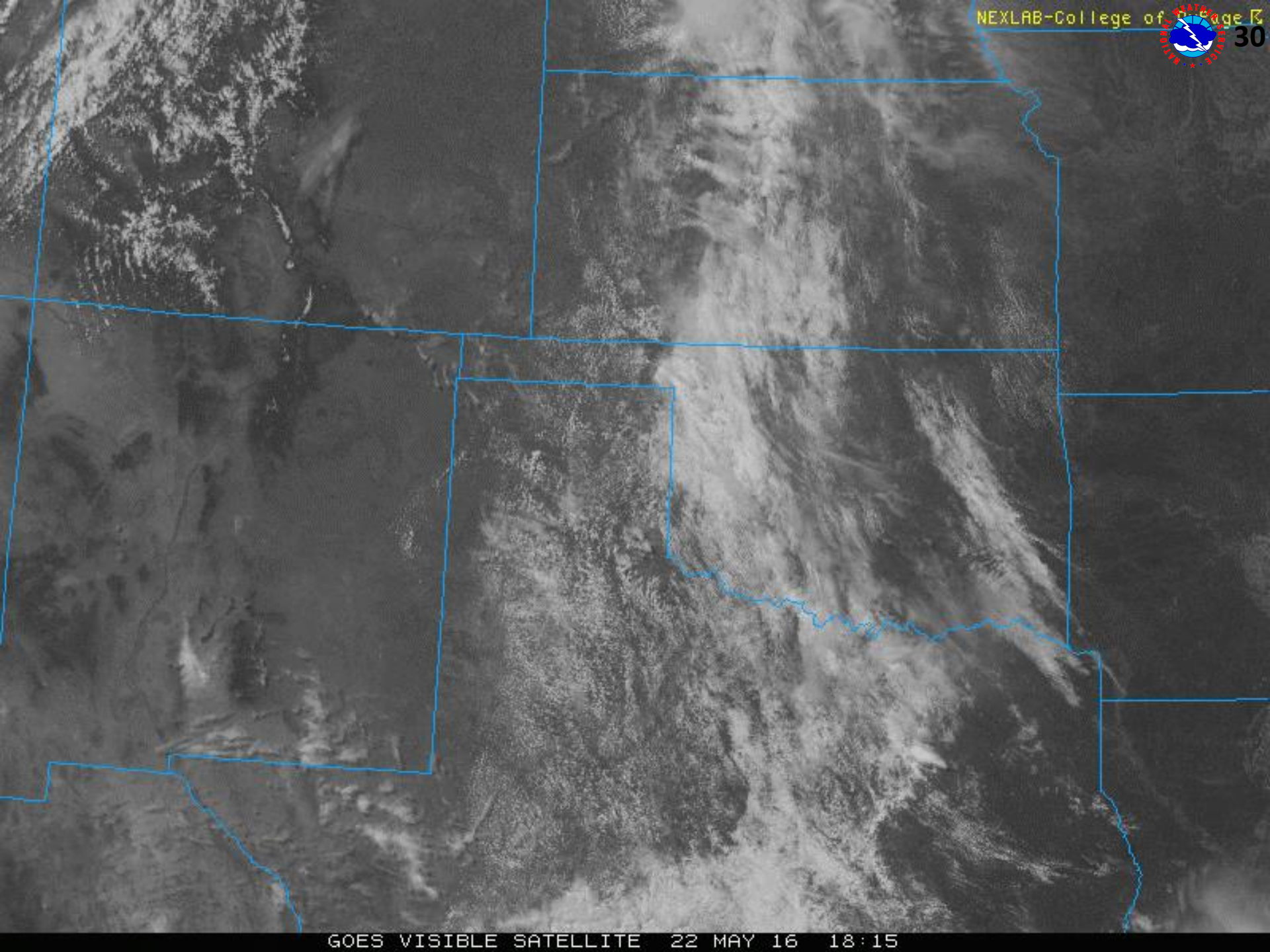
- ~40,000 to 60,000 feet tall
- Strong updraft and downdraft coexist
- Large hail, damaging winds, tornado(es), and flooding rain may occur

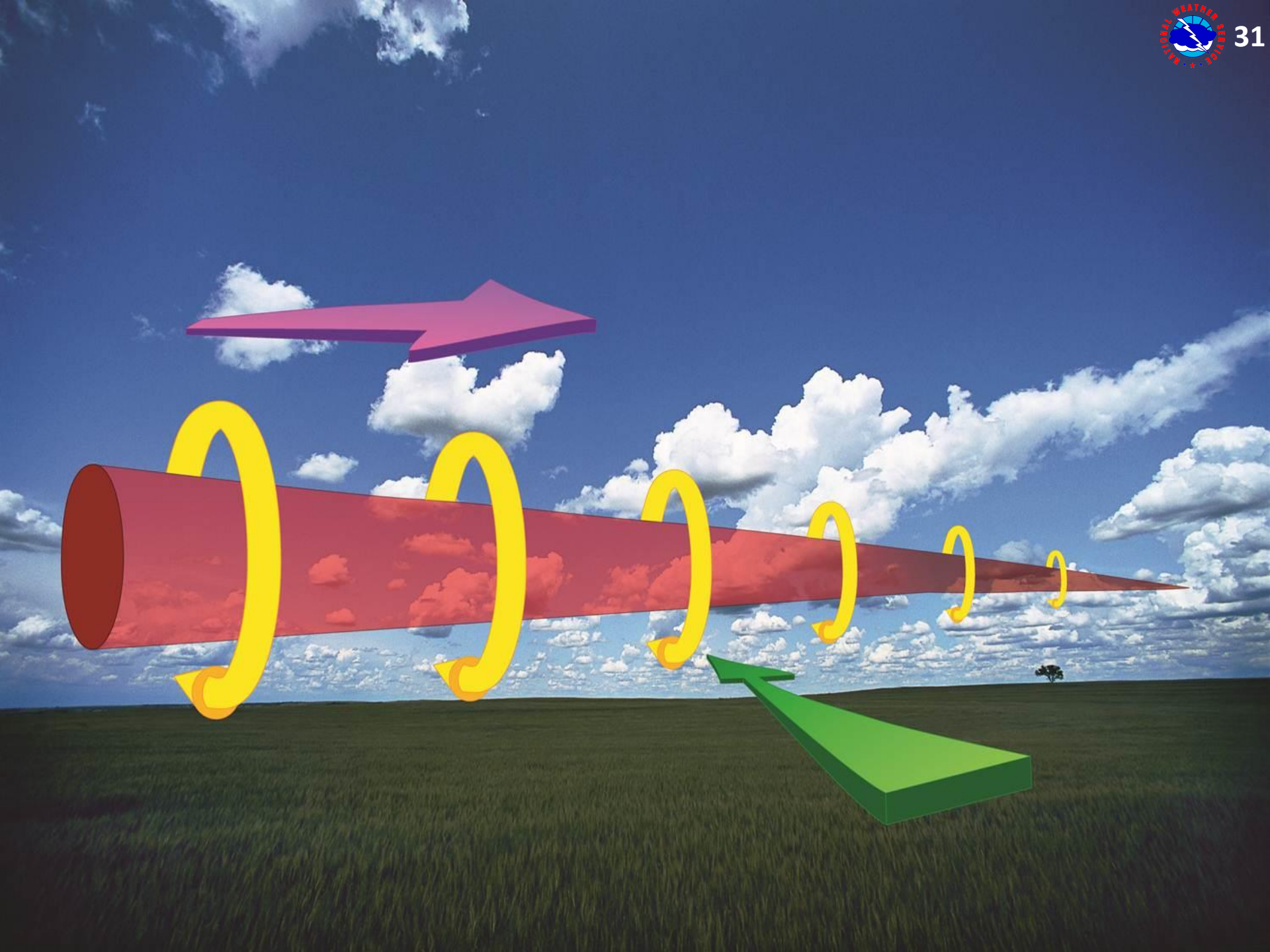


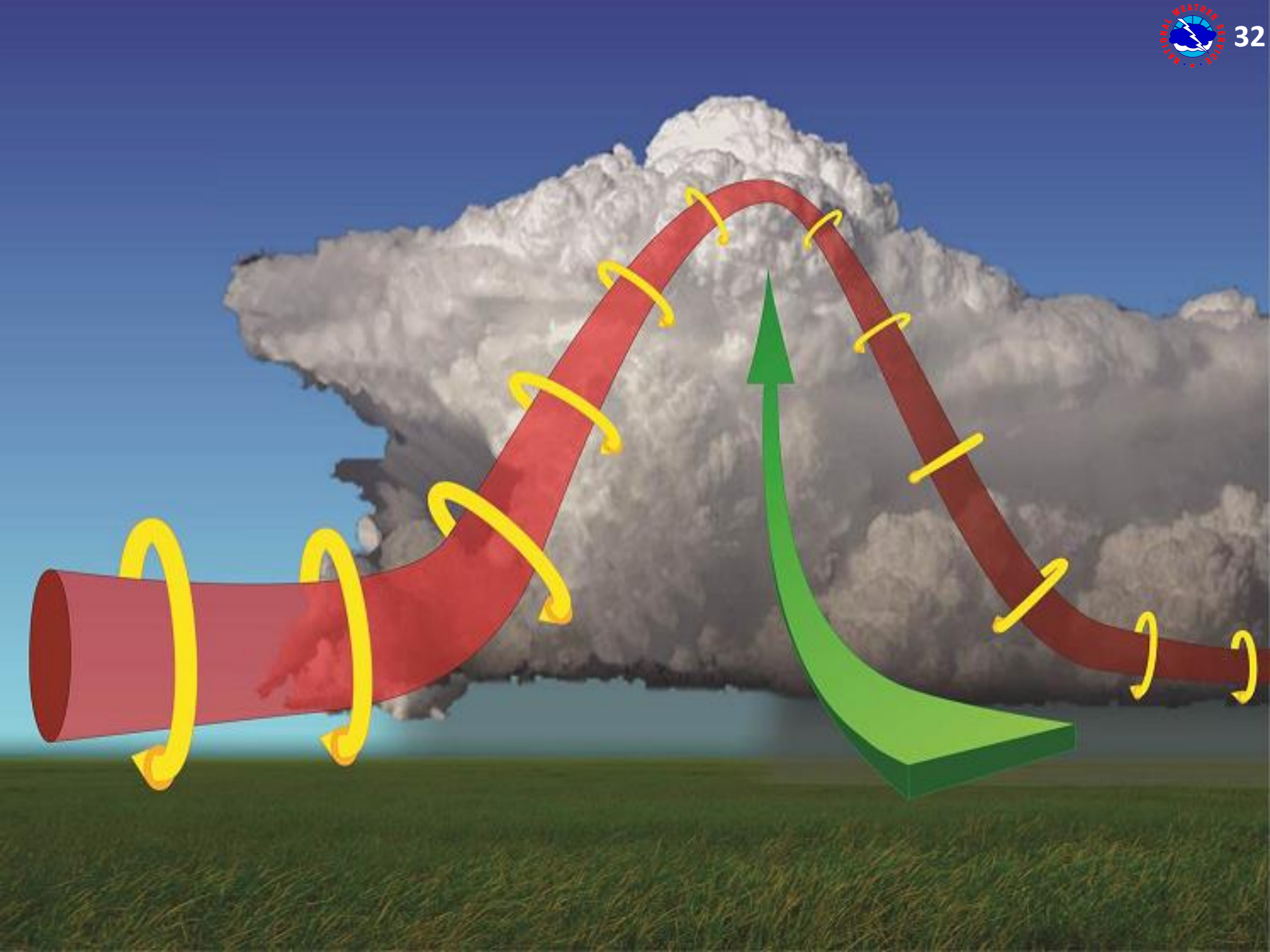
- Downdraft cuts off updraft
- Rain, gusty winds, and last lightning strike
- Remnant anvil cloud aloft

Stages of Activity

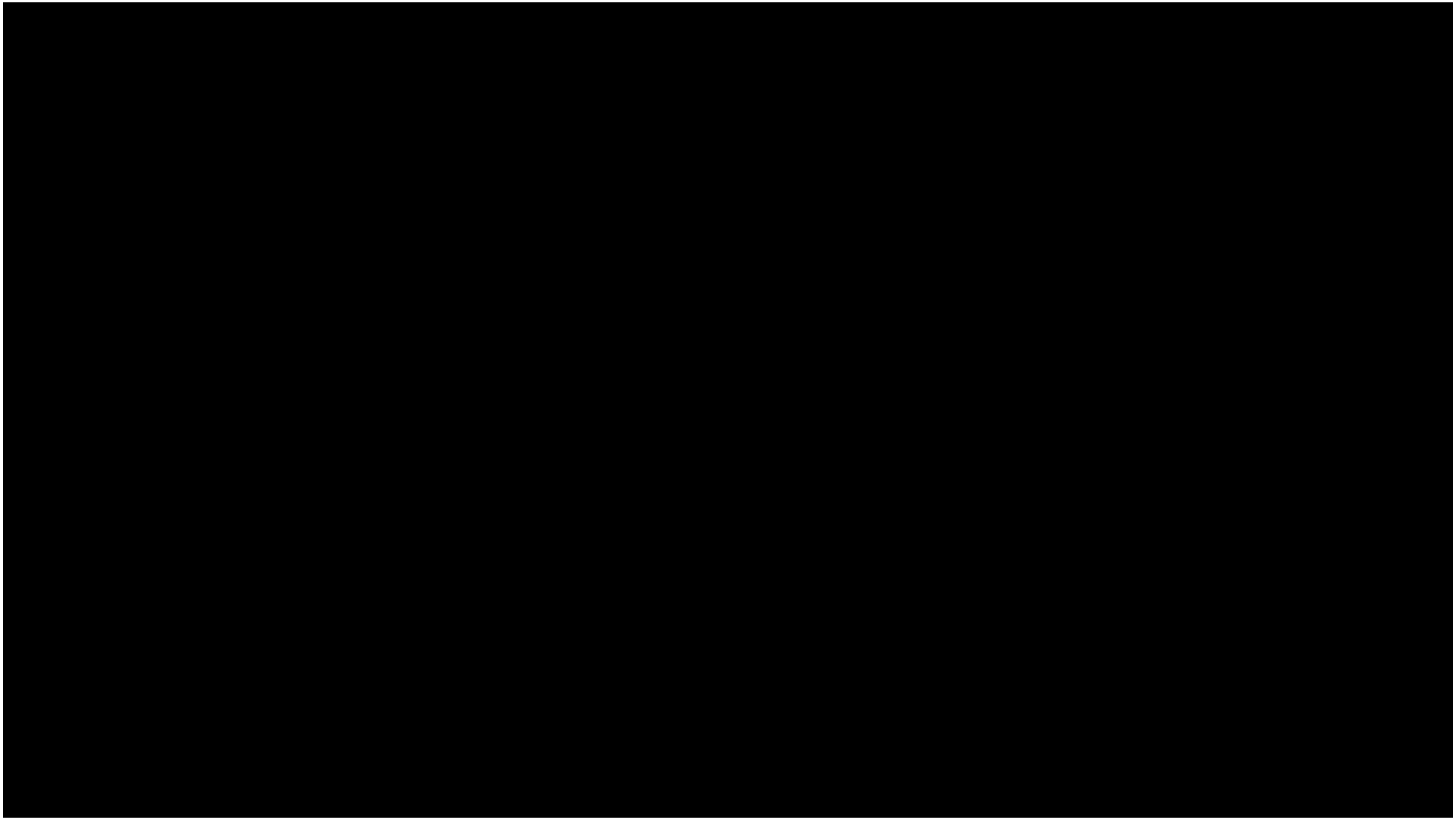



NEXLAB-College of DuPage
30
GOES VISIBLE SATELLITE 22 MAY 16 18:15



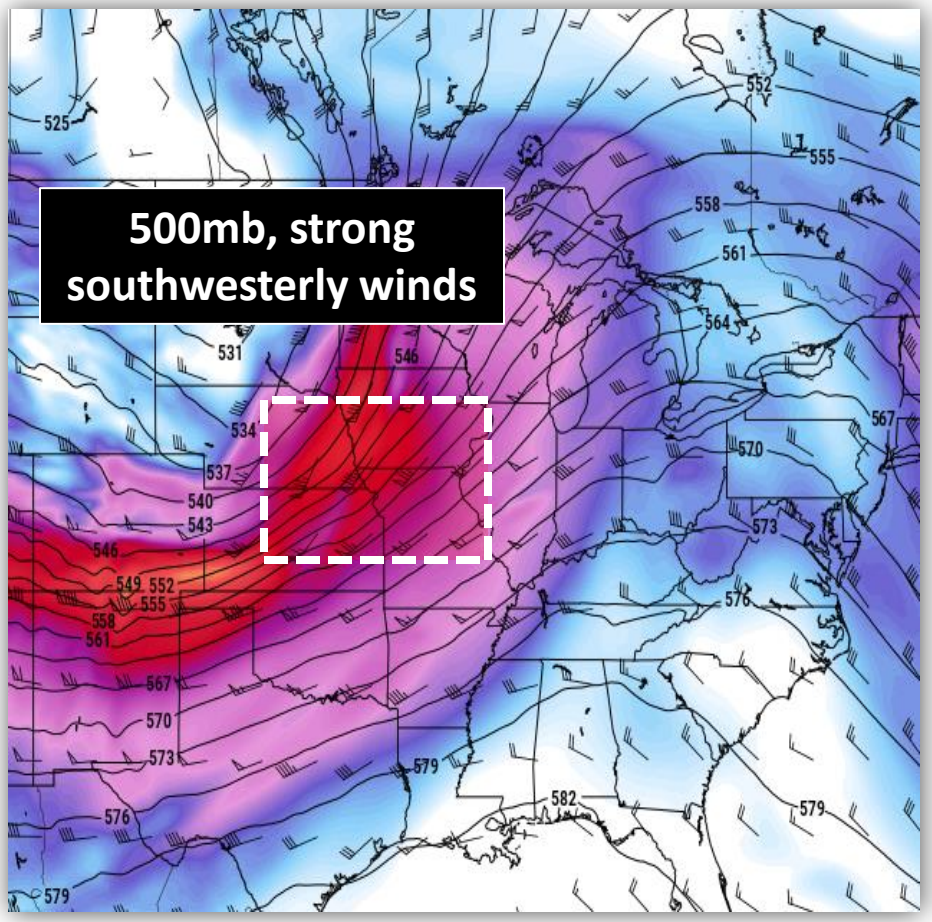


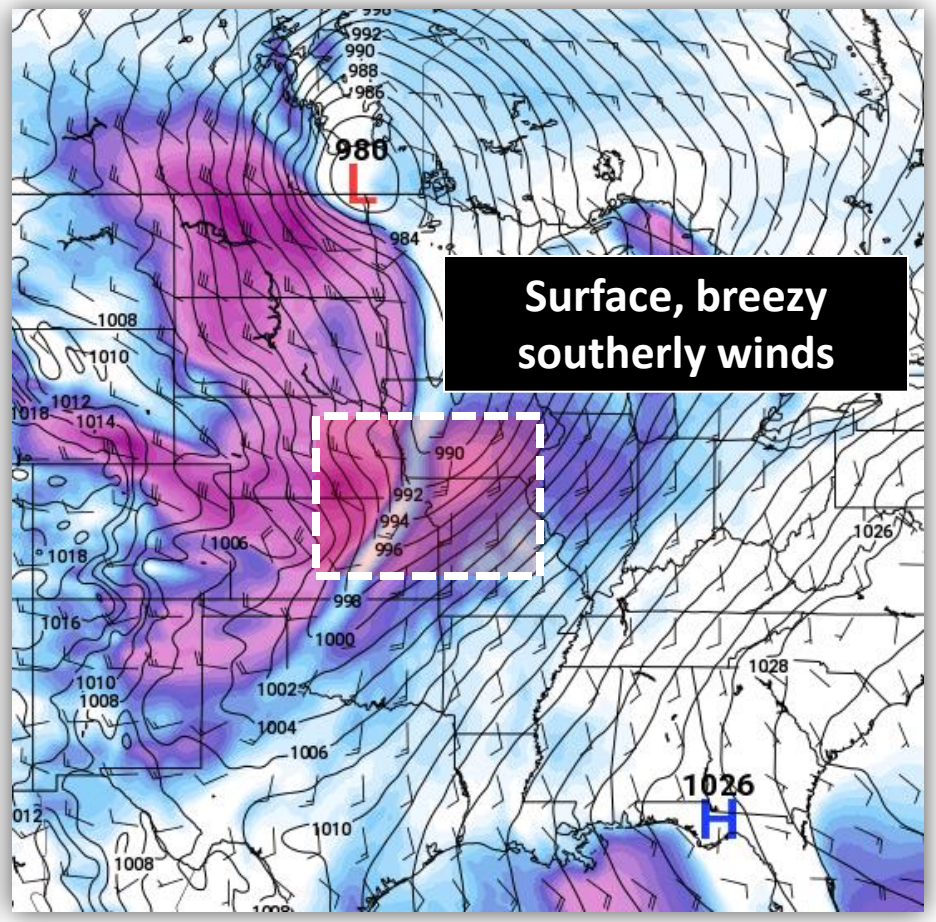
GOES-16 One-Minute Imagery!!



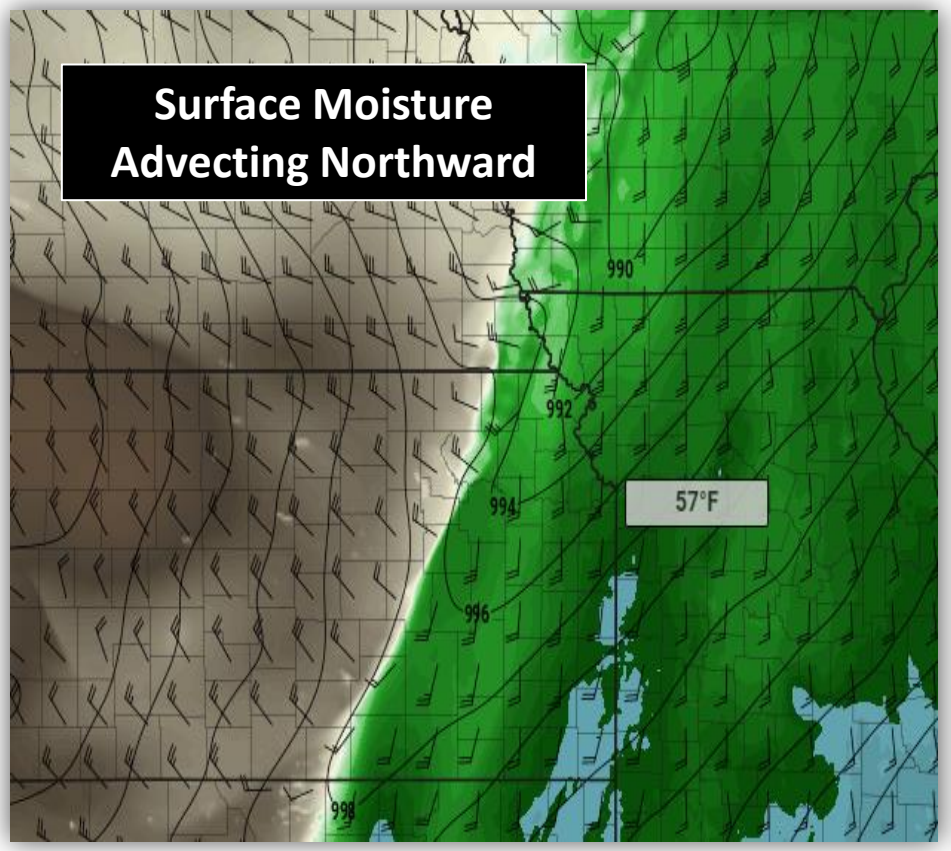
Let's Demo an Event!
Yesterday – March 06th 2017

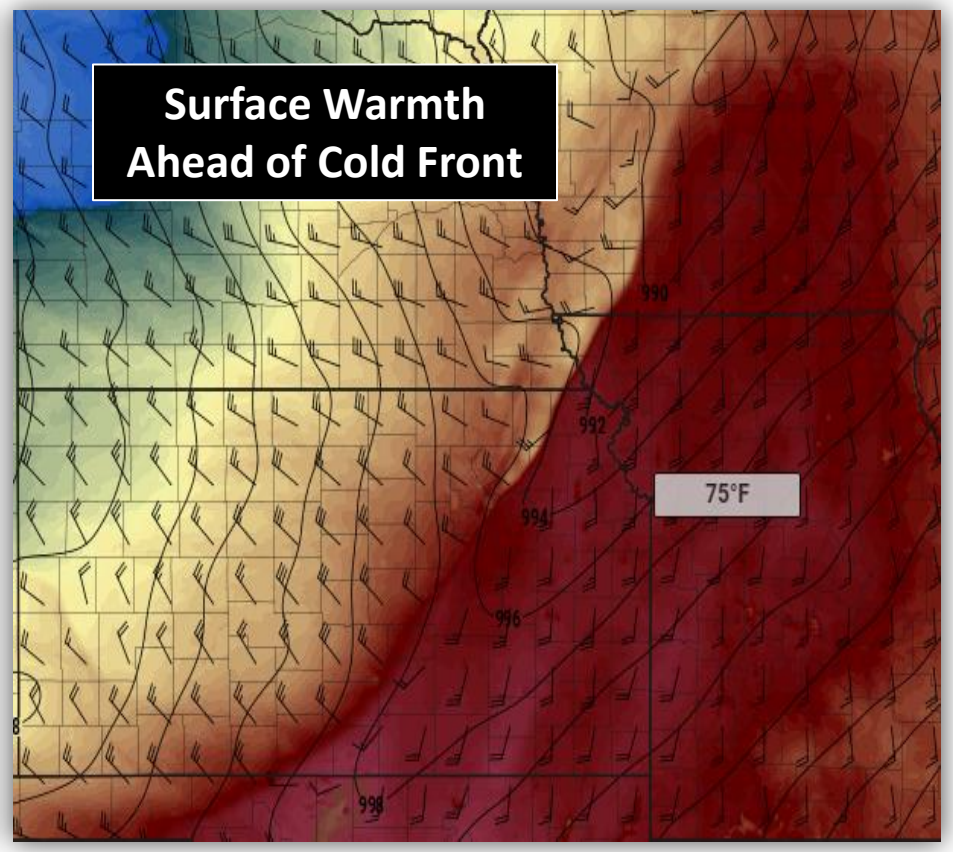
Overall Setup



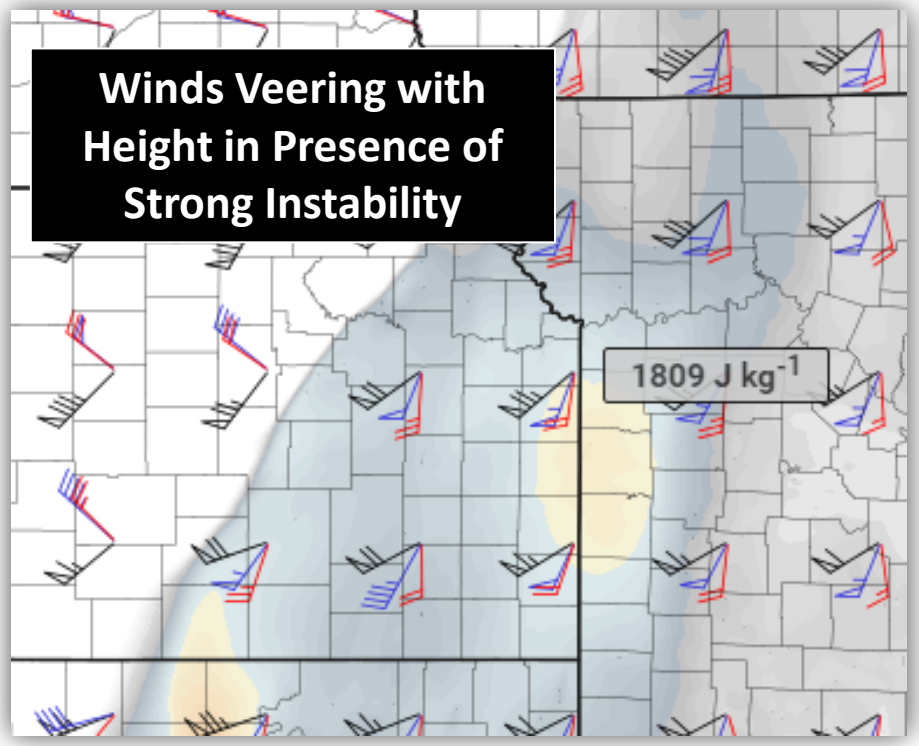


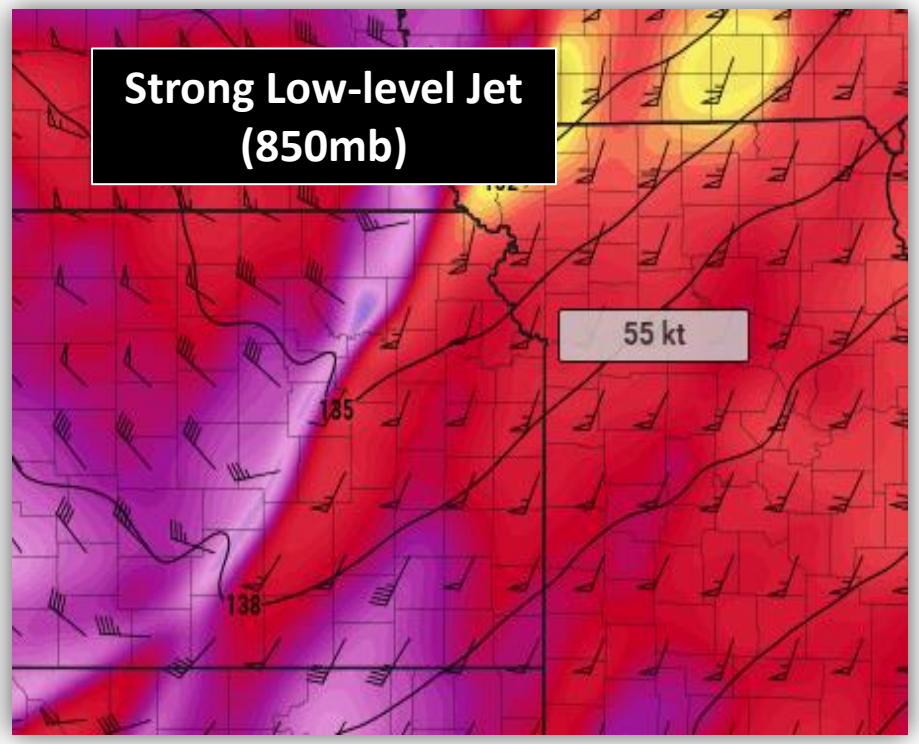
Overall Setup - Instability



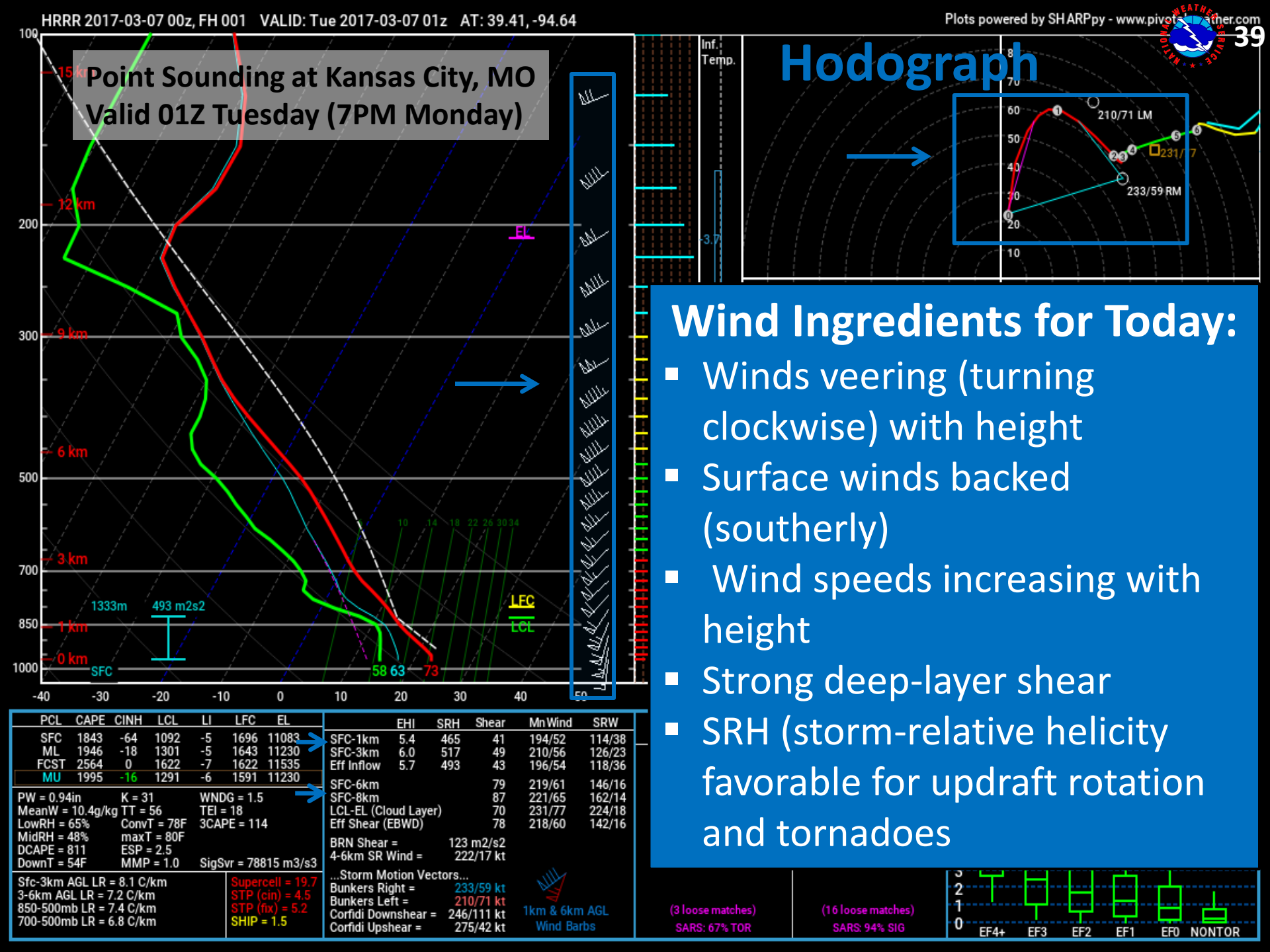


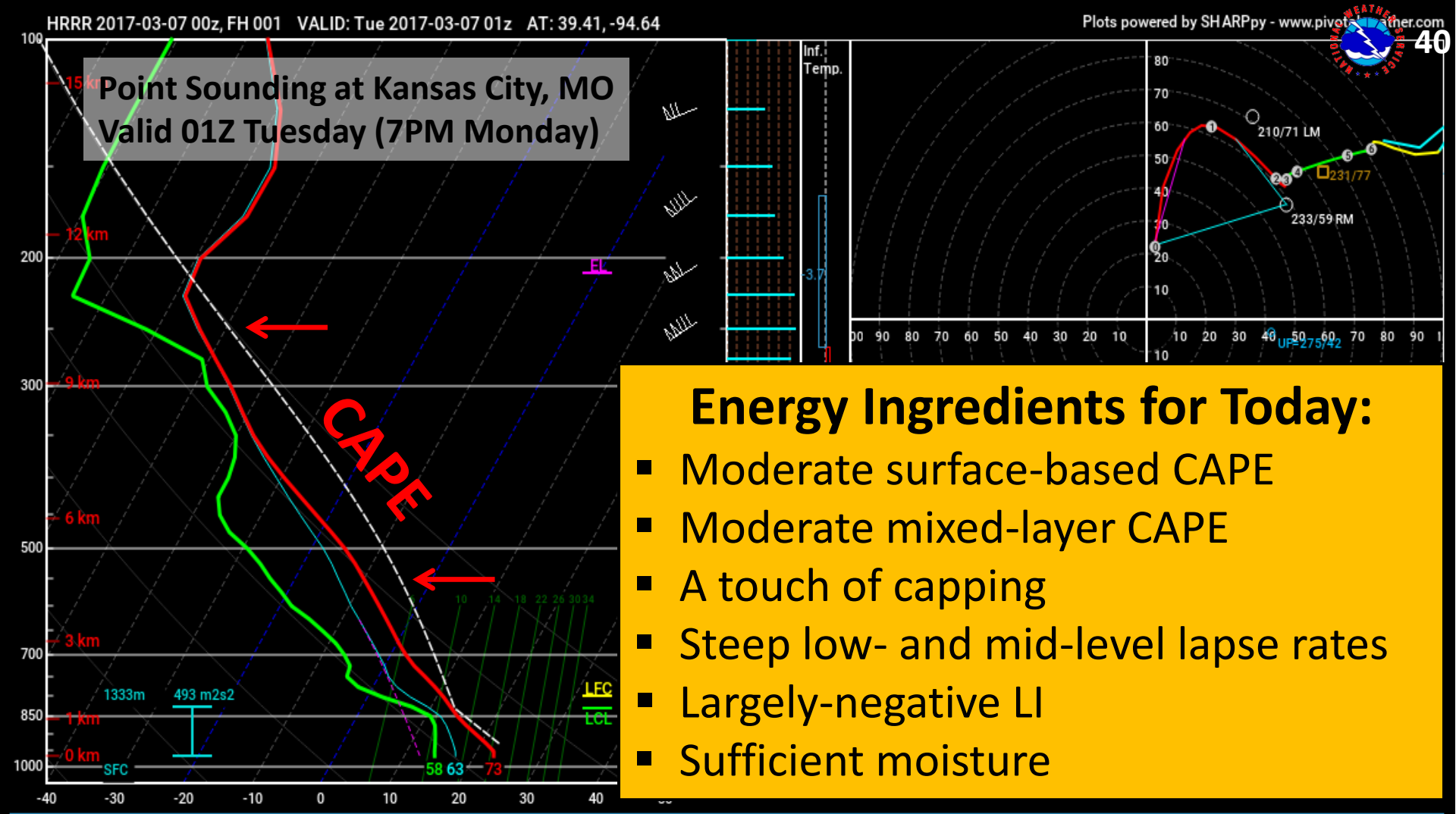
Overall Setup – Wind Shear





Crossover (kt) at 500 mb, 850 mb, 10 m AGL


HRRR 2017-03-07 00z, FH 001 VALID: Tue 2017-03-07 01z AT: 39.41, -94.64
Plots powered by SHARPpy - www.pivotalweather.com
Point Sounding at Kansas City, MO
Valid 01Z Tuesday (7PM Monday)
Hodograph
210/71 LM
233/59 RM
231/7
Wind Ingredients for Today:
Winds veering (turning clockwise) with height
Surface winds backed (southerly)
Wind speeds increasing with height
Strong deep-layer shear
SRH (storm-relative helicity favorable for updraft rotation and tornadoes
PCL CAPE CINH LCL LI LFC EL
SFC 1843 -64 1092 -5 1696 11083
ML 1946 -18 1301 -5 1643 11230
FCST 2564 0 1622 -7 1622 11535
MU 1995 -16 1291 -6 1591 11230
PW = 0.94in K = 31 WNDG = 1.5
MeanW = 10.4g/kg TT = 56 TEI = 18
LowRH = 65% ConvT = 78F 3CAPE = 114
MidRH = 48% maxT = 80F
DCAPE = 811 ESP = 2.5
DownT = 54F MMP = 1.0 SigSvr = 78815 m3/s3
Sfc-3km AGL LR = 8.1 C/km
3-6km AGL LR = 7.2 C/km
850-500mb LR = 7.4 C/km
700-500mb LR = 6.8 C/km
Supercell = 19.7
STP (cin) = 4.5
STP (fix) = 5.2
SHIP = 1.5
EHI SRH Shear MnWind SRW
SFC-1km 5.4 465 41 194/52 114/38
SFC-3km 6.0 517 49 210/56 126/23
Eff Inflow 5.7 493 43 196/54 118/36
SFC-6km 79 219/61 146/16
SFC-8km 87 221/65 162/14
LCL-EL (Cloud Layer) 70 231/77 224/18
Eff Shear (EBWD) 78 218/60 142/16
BRN Shear = 123 m2/s2
4-6km SR Wind = 222/17 kt
...Storm Motion Vectors...
Bunkers Right = 233/59 kt
Bunkers Left = 210/71 kt
Corfidi Downshear = 246/111 kt
Corfidi Upshear = 275/42 kt
1km & 6km AGL Wind Barbs
(3 loose matches)
SARS: 67% TOR
(16 loose matches)
SARS: 94% SIG
EF4+ EF3 EF2 EF1 EF0 NONTOR



Energy Ingredients for Today:

- Moderate surface-based CAPE
- Moderate mixed-layer CAPE
- A touch of capping
- Steep low- and mid-level lapse rates
- Largely-negative LI
- Sufficient moisture

PCL	CAPE	CINH	LCL	LI	LFC	EL
SFC	1843	-64	1092	-5	1696	11083
ML	1946	-18	1301	-5	1643	11230
FCST	2564	0	1622	-7	1622	11535
MU	1995	-16	1291	-6	1591	11230

PW = 0.94in | K = 31 | WNDG = 1.5
MeanW = 10.4g/kg | TT = 56 | TEI = 18
LowRH = 65% | ConvT = 78F | 3CAPE = 114
MidRH = 48% | maxT = 80F
DCAPE = 811 | ESP = 2.5
DownT = 54F | MMP = 1.0 | SigSvr = 78815 m3/s3

Sfc-3km AGL LR = 8.1 C/km
3-6km AGL LR = 7.2 C/km
850-500mb LR = 7.4 C/km
700-500mb LR = 6.8 C/km

Supercell = 19.7
STP (cin) = 4.5
STP (fix) = 5.2
SHIP = 1.5

	EHI	SRH	Shear	MnWind	SRW
SFC-1km	5.4	465	41	194/52	114/38
SFC-3km	6.0	517	49	210/56	126/23
Eff Inflow	5.7	493	43	196/54	118/36
SFC-6km			79	219/61	146/16
SFC-8km			87	221/65	162/14
LCL-EL (Cloud Layer)			70	231/77	224/18
Eff Shear (EBWD)			78	218/60	142/16

BRN Shear = 123 m2/s2
4-6km SR Wind = 222/17 kt

...Storm Motion Vectors...
Bunkers Right = 233/59 kt
Bunkers Left = 210/71 kt
Corfidi Downshear = 246/111 kt
Corfidi Upshear = 275/42 kt

1km & 6km AGL Wind Barbs

SARS - Sounding Analogs

SUPERCELL	SGFNT HAIL
No Quality Matches	No Quality Matches
(3 loose matches)	(16 loose matches)
SARS: 67% TOR	SARS: 94% SIG

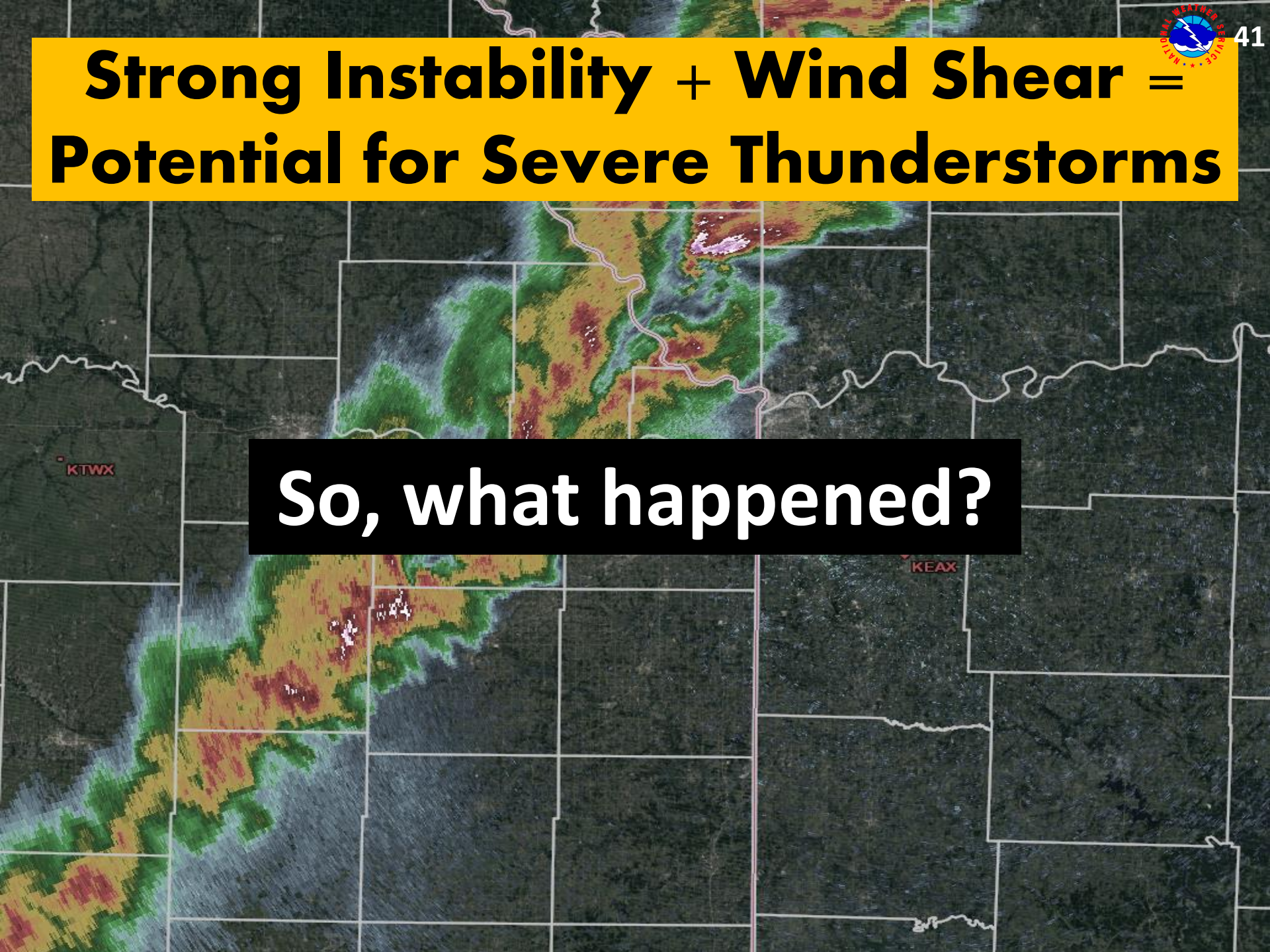
Effective Layer STP (with CIN)

Prob EF2+ torn with supercell
Sample CLIMO = .15 sigtor

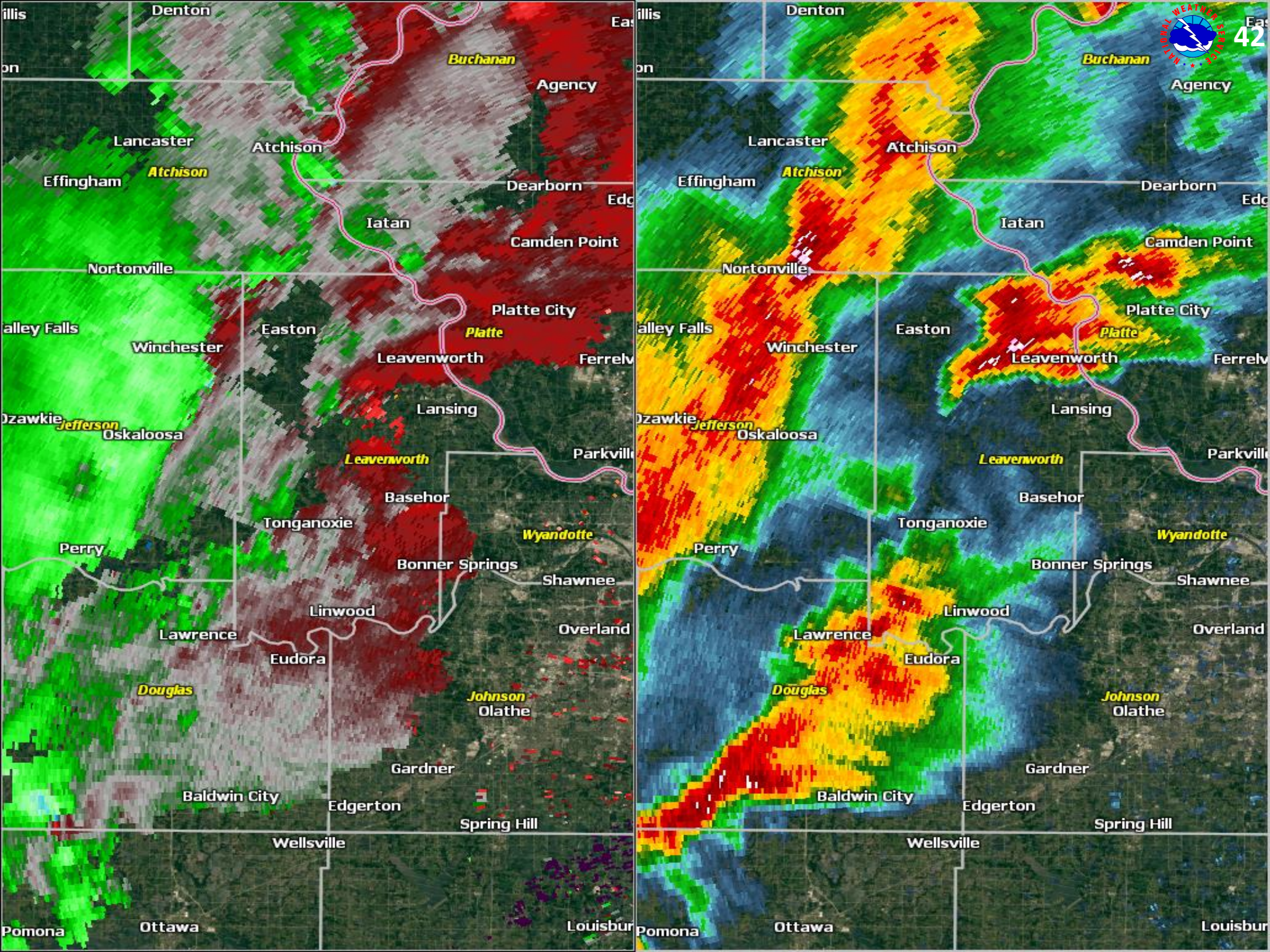
based on CAPE:	0.13
based on LCL:	0.1
based on ESRH:	0.27
based on EBWD:	0.36
based on STPC:	0.32
based on STP_fixed:	0.39

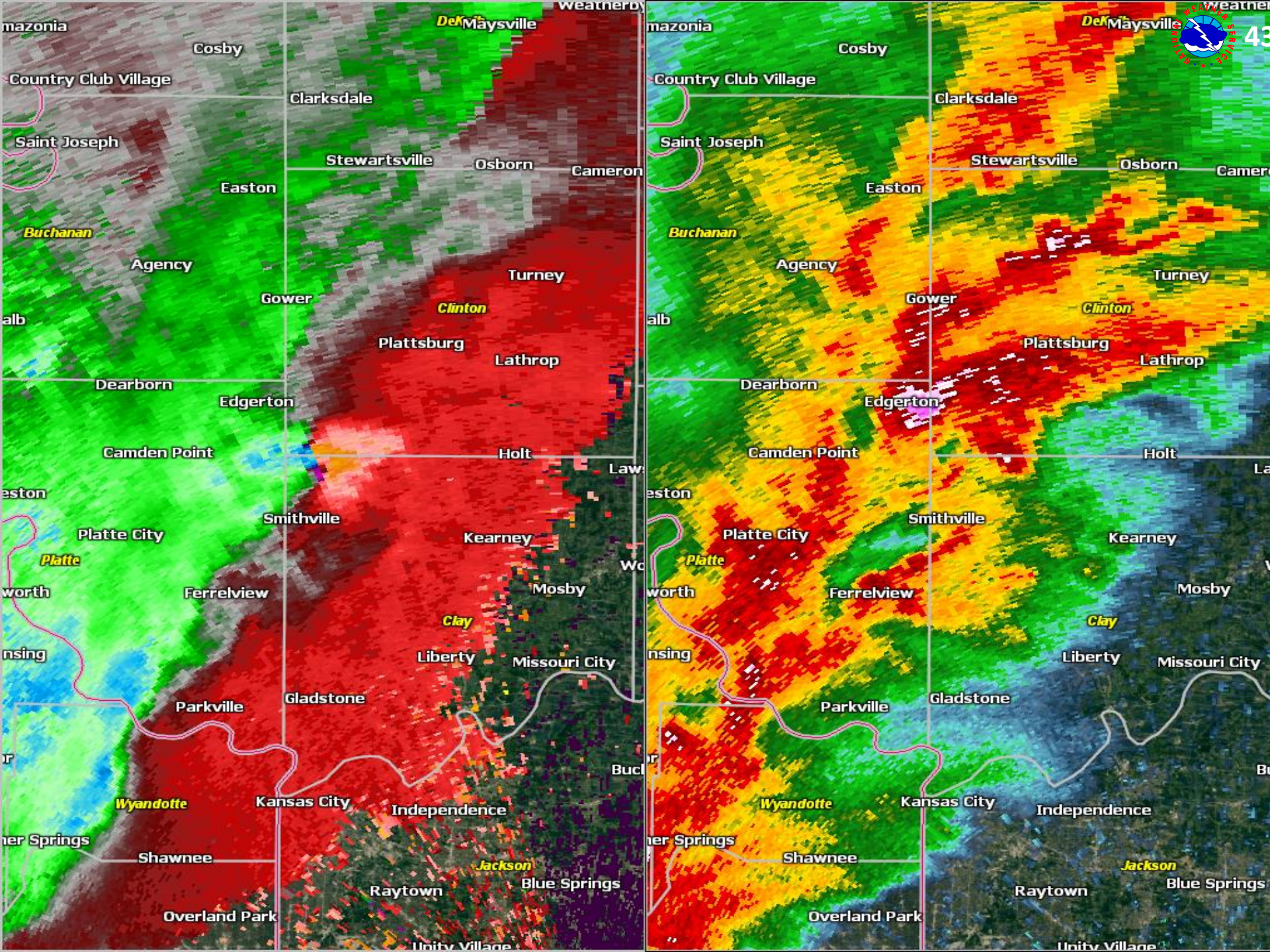
EF4+ EF3 EF2 EF1 EF0 NONTOR

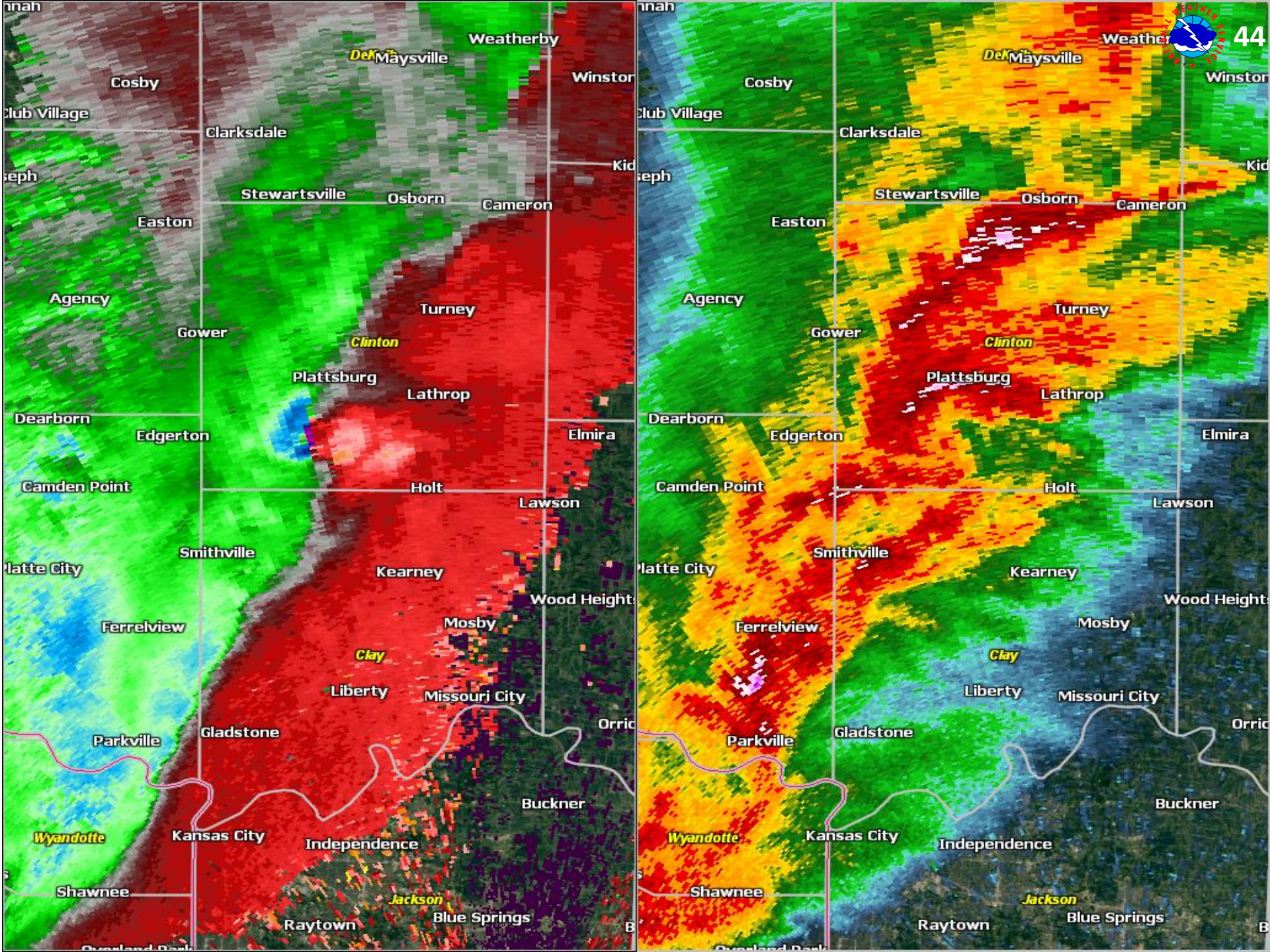
Strong Instability + Wind Shear = Potential for Severe Thunderstorms

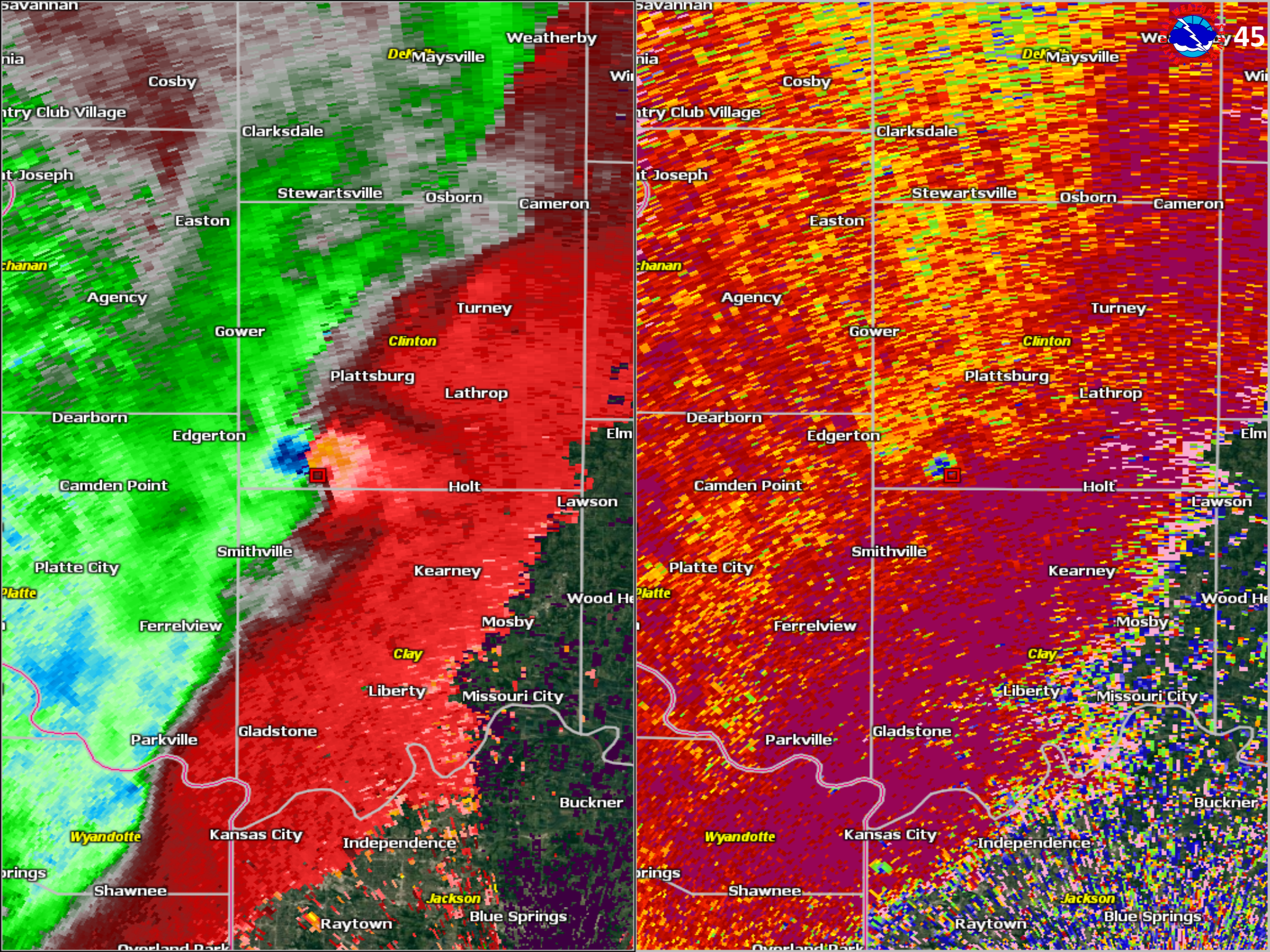


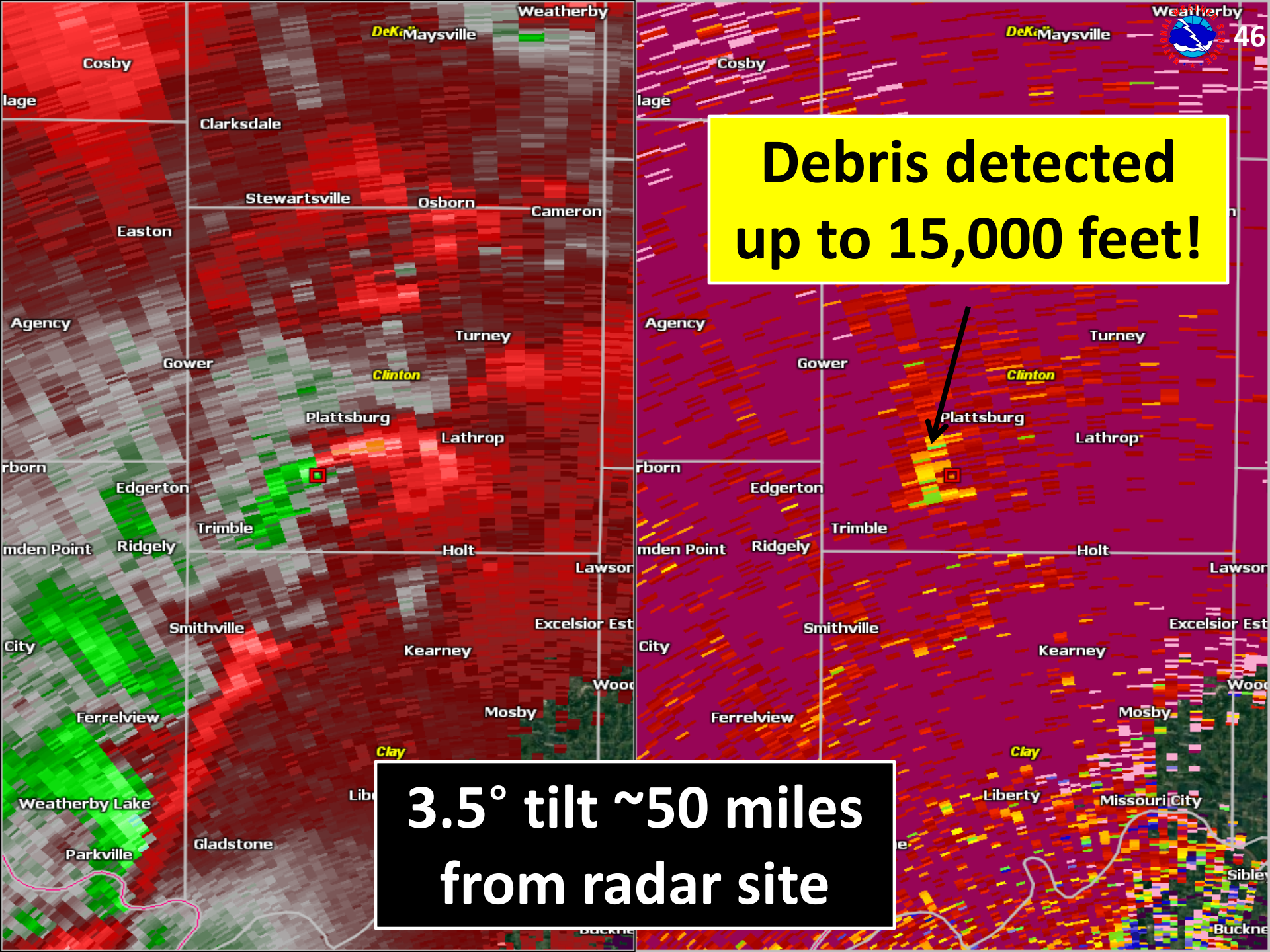
So, what happened?

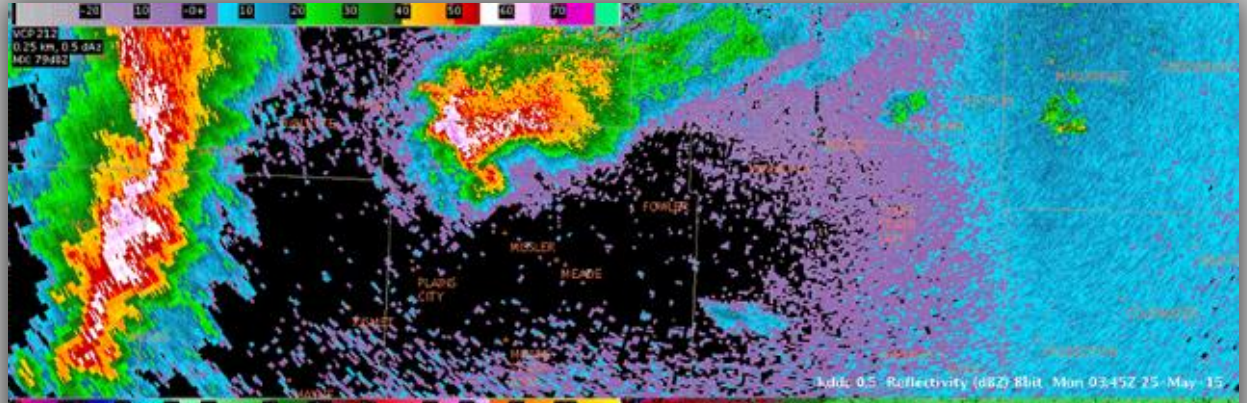

Denton
Buchanan
Agency
Lancaster
Atchison
Effingham
Atchison
Dearborn
Iatan
Camden Point
Nortonville
Platte City
Platte
Easton
Winchester
Leavenworth
Lansing
Jefferson
Oskaloosa
Leavenworth
Basehor
Tonganoxie
Wyandotte
Perry
Bonner Springs
Shawnee
Linwood
Lawrence
Overland
Eudora
Douglas
Johnson
Olathe
Gardner
Baldwin City
Edgerton
Spring Hill
Wellsville
Pomona
Ottawa
42


Maysville
Cosby
Country Club Village
Clarksdale
Saint Joseph
Stewartsville
Osborn
Cameron
Easton
Buchanan
Agency
Turney
Gower
Clinton
Plattsburg
Lathrop
Dearborn
Edgerton
Camden Point
Holt
Smithville
Platte City
Platte
Kearney
Ferrelview
Mosby
Clay
Liberty
Missouri City
Parkville
Gladstone
Wyandotte
Kansas City
Independence
Shawnee
Jackson
Raytown
Blue Springs
Overland Park
Unity Village


Weatherby
DeKalb
Maysville
Cosby
Winston
Clarksdale
Stewartsville
Osborn
Cameron
Easton
Agency
Turney
Gower
Clinton
Plattsburg
Lathrop
Dearborn
Edgerton
Elmira
Camden Point
Holt
Lawson
Smithville
Kearney
Ferrelview
Mosby
Wood Heights
Clay
Liberty
Missouri City
Parkville
Gladstone
Buckner
Wyandotte
Kansas City
Independence
Shawnee
Jackson
Raytown
Blue Springs
44


Savannah
Weatherby
Maysville
Cosby
Clarksdale
Stewartsville
Osborn
Cameron
Easton
Agency
Turney
Gower
Clinton
Plattsburg
Lathrop
Dearborn
Edgerton
Camden Point
Holt
Lawson
Smithville
Platte City
Kearney
Ferrelview
Mosby
Clay
Liberty
Missouri City
Parkville
Gladstone
Buckner
Wyandotte
Kansas City
Independence
Shawnee
Jackson
Raytown
Blue Springs
45


Debris detected up to 15,000 feet!
3.5° tilt ~50 miles from radar site
Weatherby
Maysville
Cosby
Clarksdale
Stewartsville
Osborn
Cameron
Easton
Agency
Turney
Gower
Clinton
Plattsburg
Lathrop
Edgerton
Trimble
Ridgely
Holt
Smithville
Excelsior Est
Kearney
Ferrelview
Mosby
Clay
Weatherby Lake
Parkville
Gladstone
Liberty
Missouri City
46

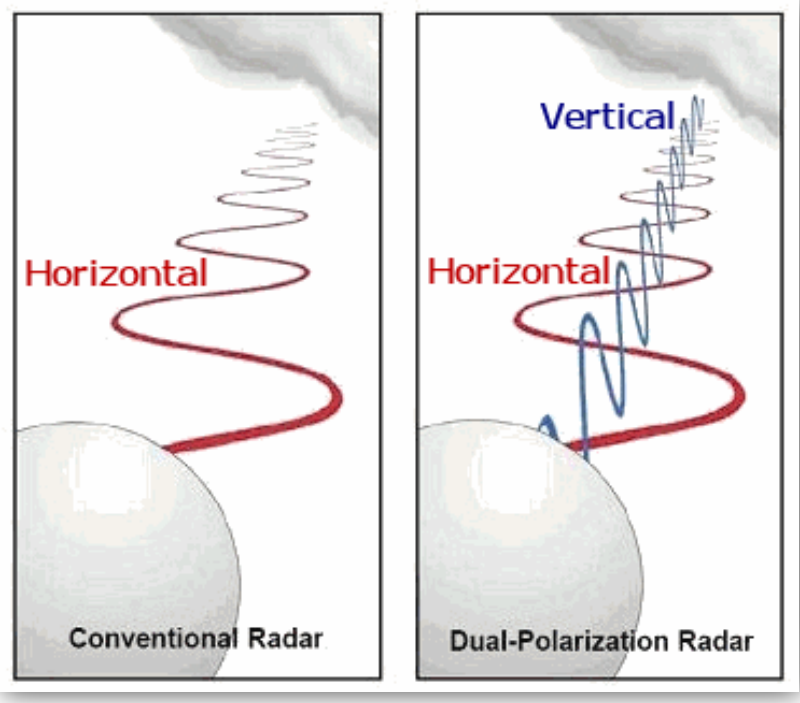


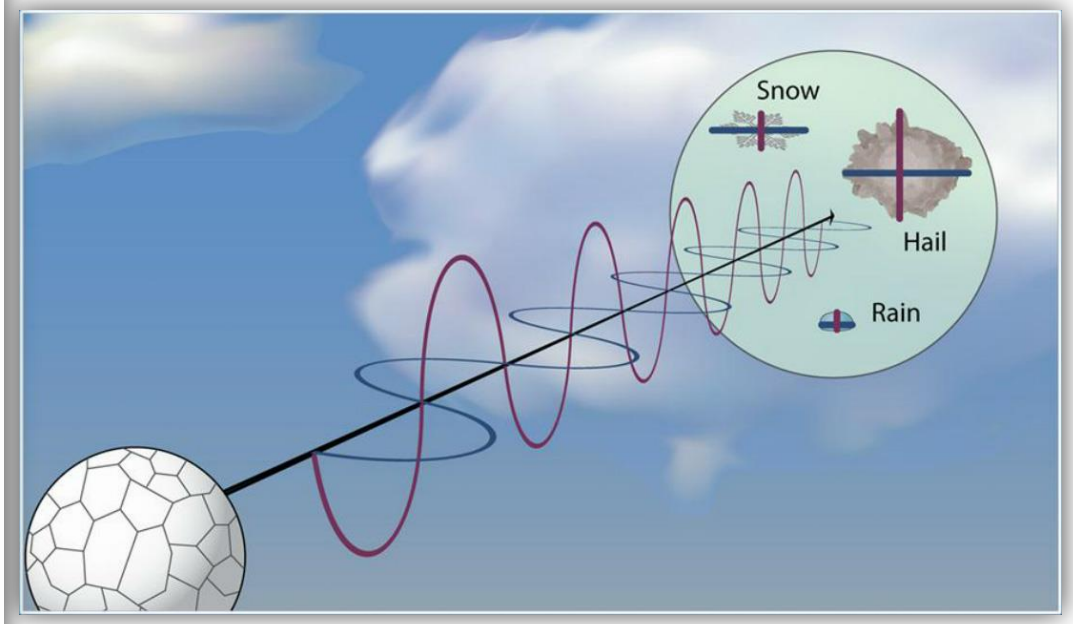
Reflectivity

Velocity

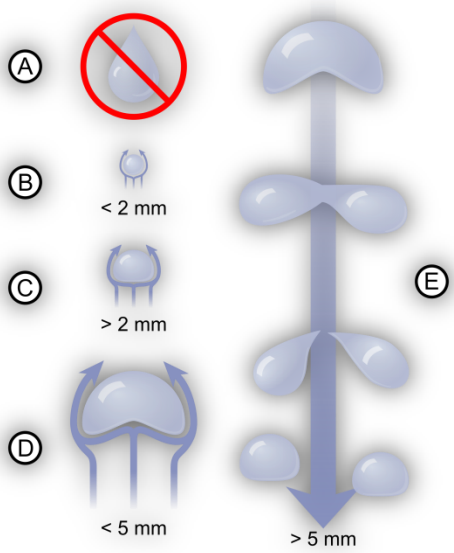
‘Out the Window’

Dual-polarization Radar





Dual-polarization Radar



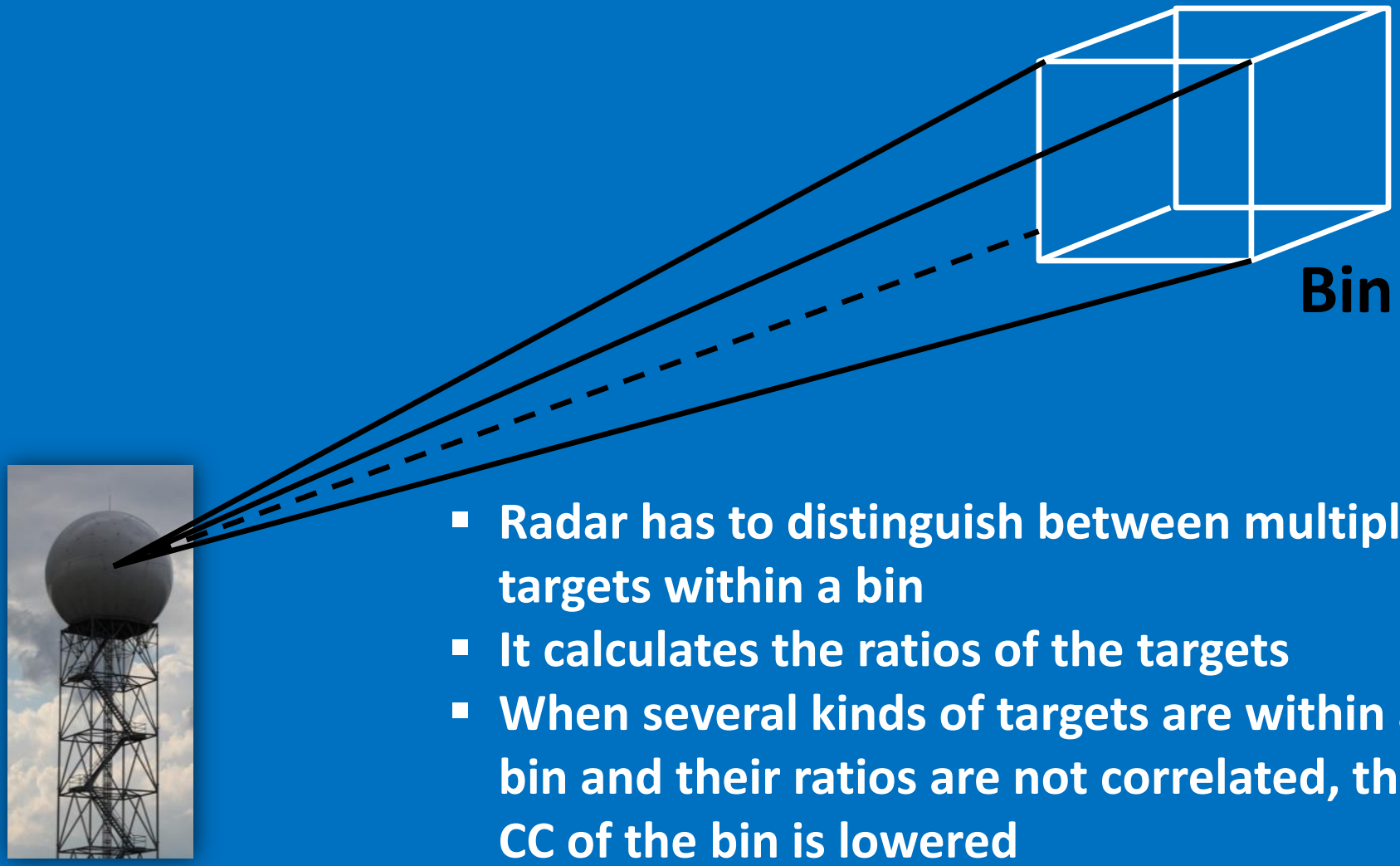
Rain

Hail

Tornado Debris

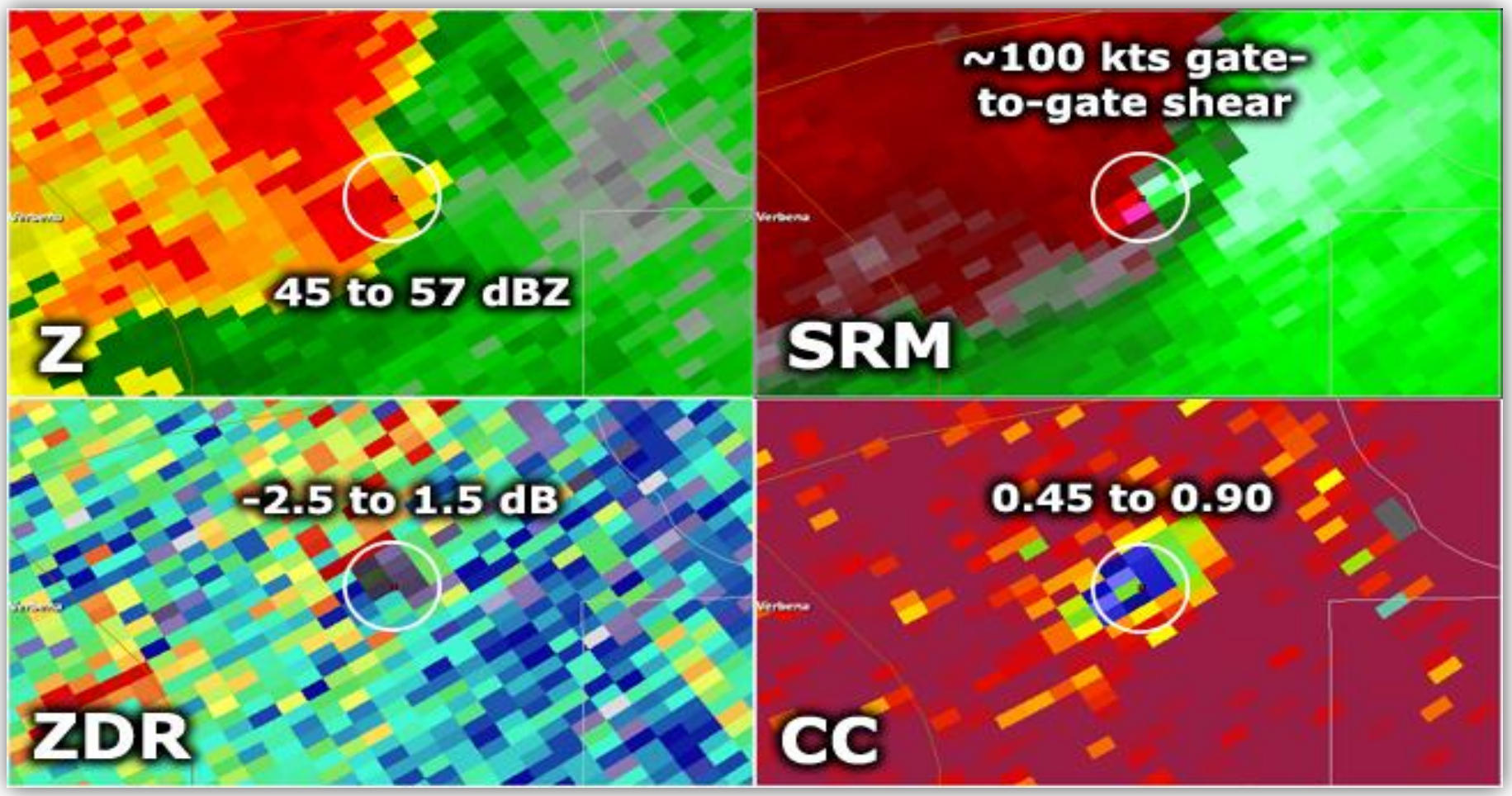
We can determine what the radar is sampling based off horizontal/vertical ratios. Weather-related, or not?

Dual-polarization Radar

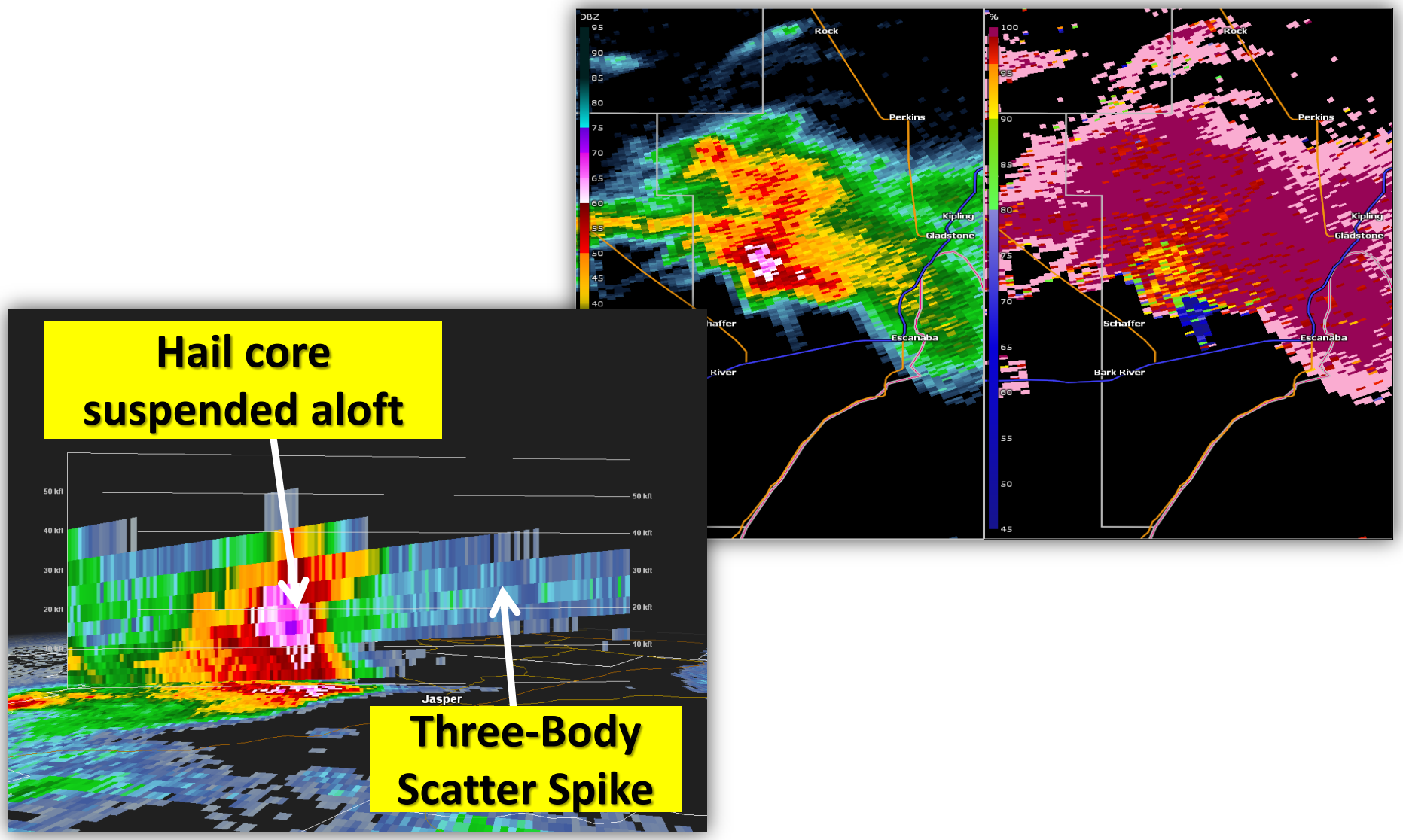


- Radar has to distinguish between multiple targets within a bin
- It calculates the ratios of the targets
- When several kinds of targets are within a bin and their ratios are not correlated, the CC of the bin is lowered

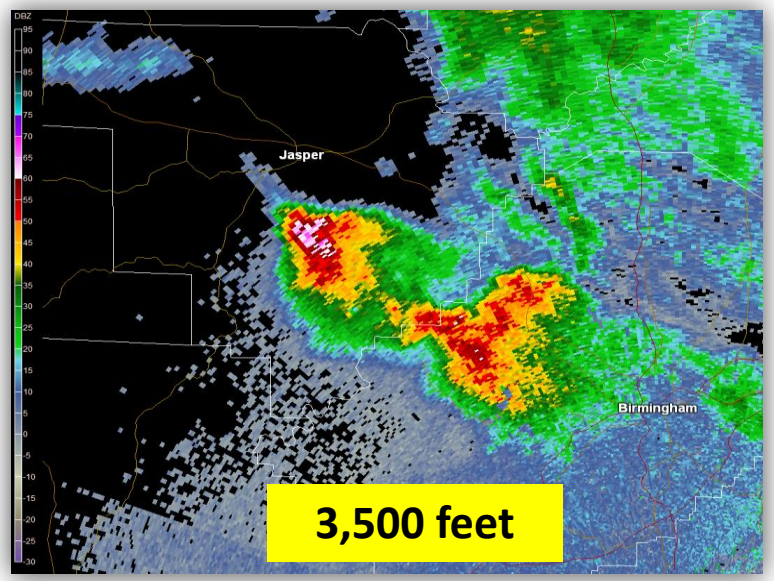
Tornado Debris Signature (TDS)

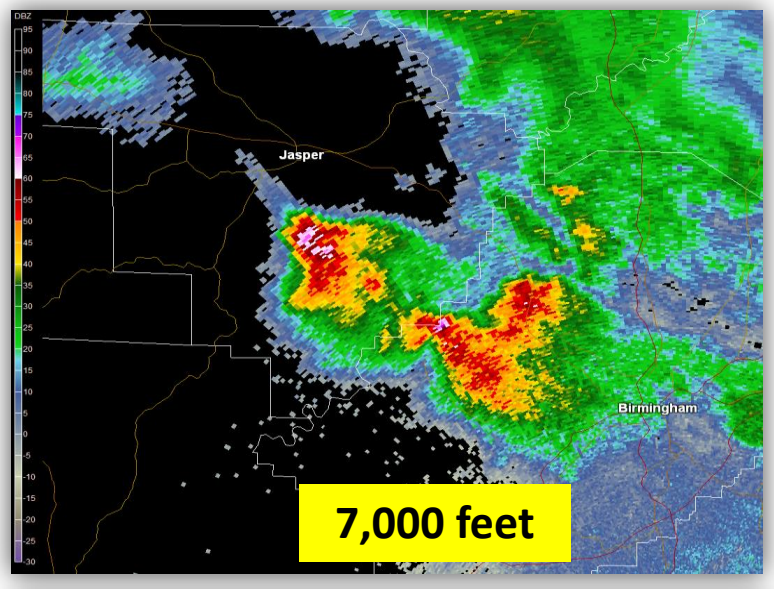


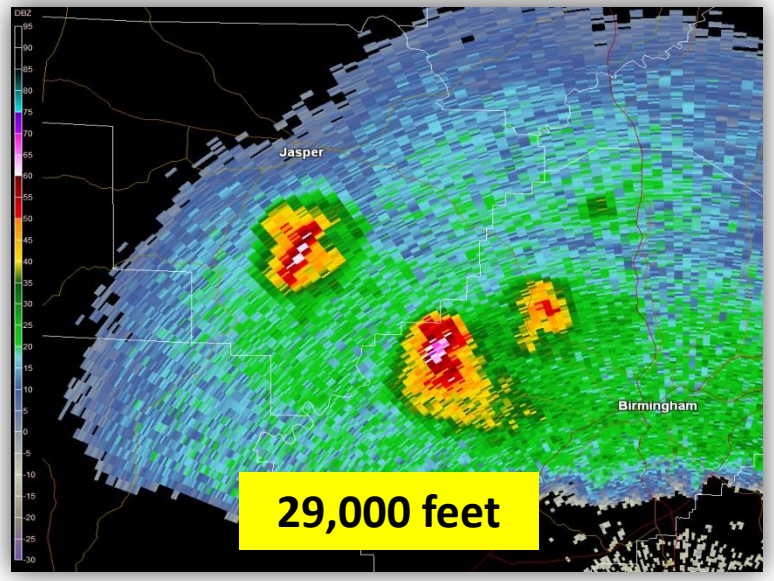
Three-Body Scatter Spike

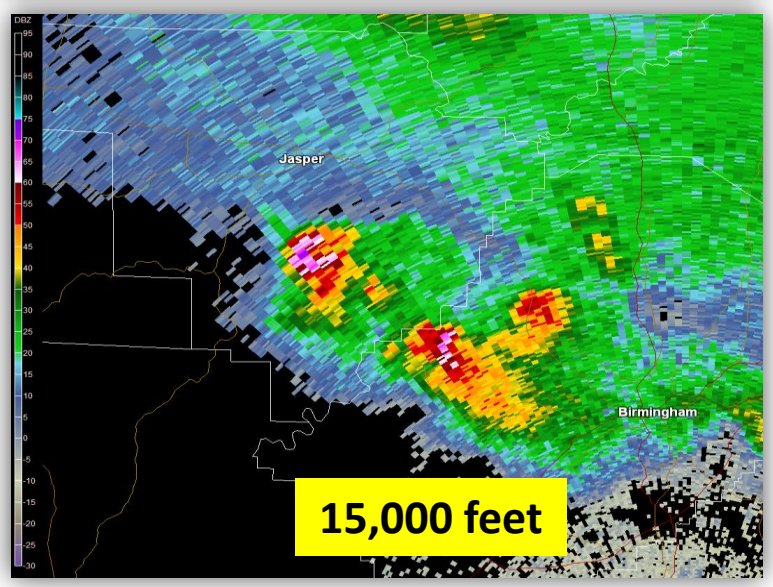


Three-Body Scatter Spike; Hail Core at X Feet Above Ground Level

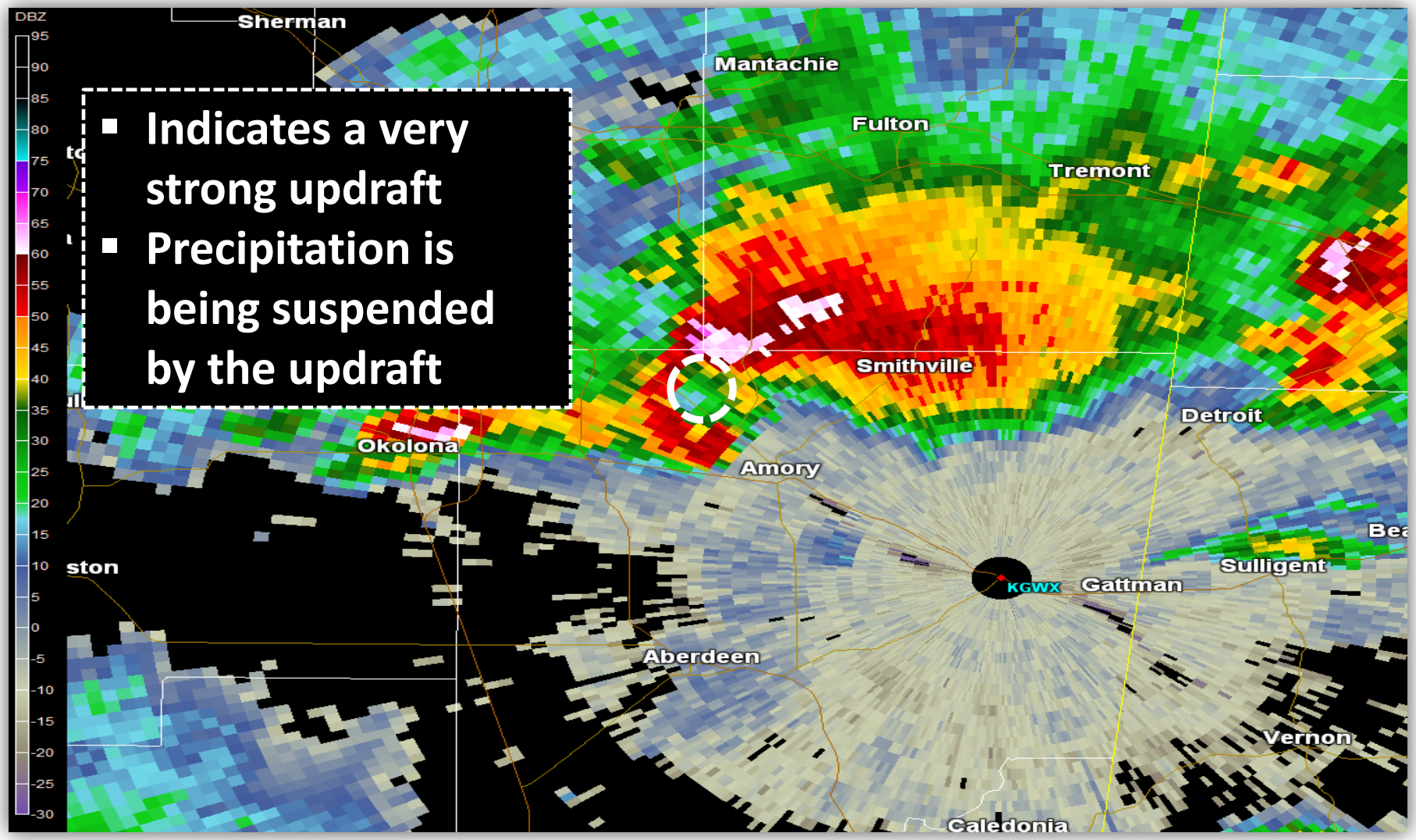






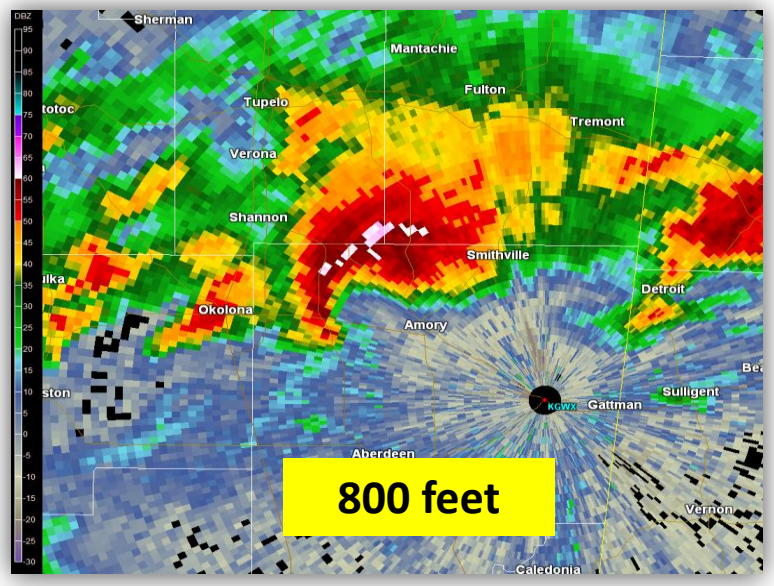


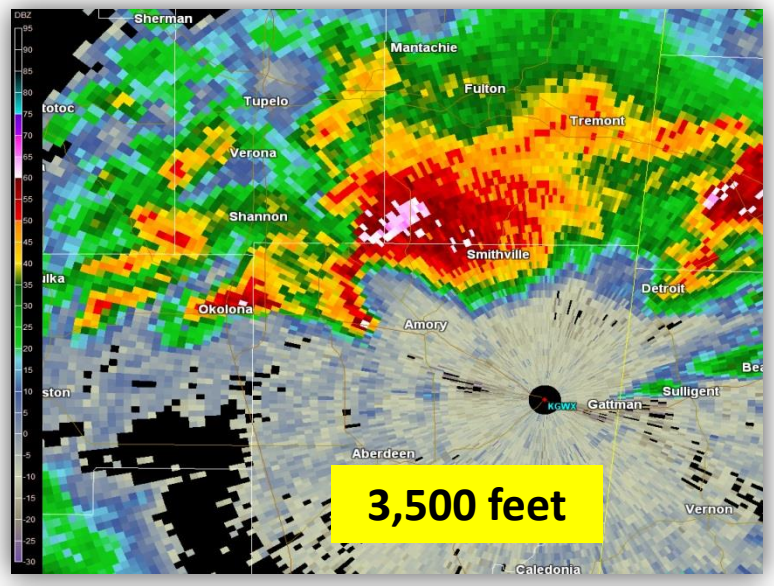
Bounded Weak Echo Region (BWER)

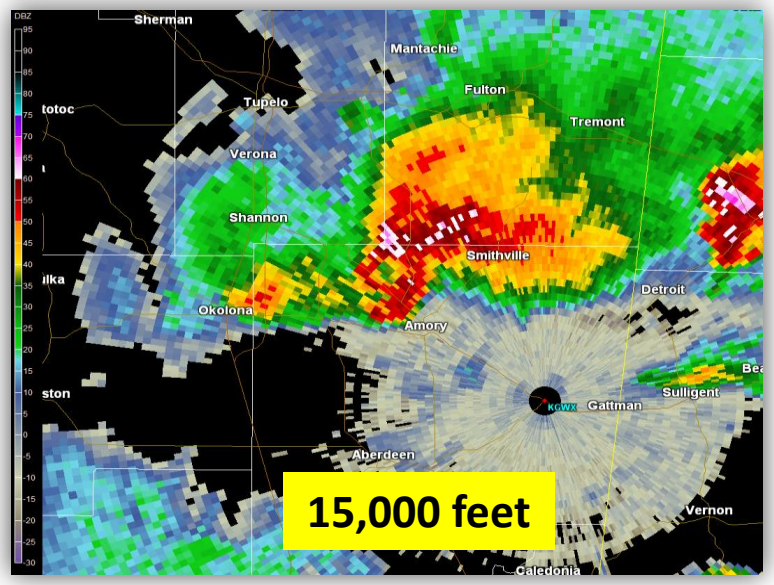


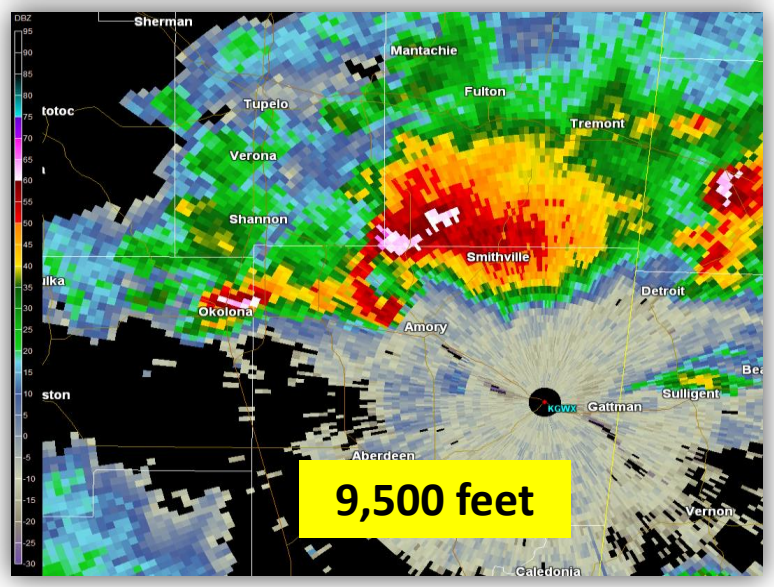
- Indicates a very strong updraft
- Precipitation is being suspended by the updraft

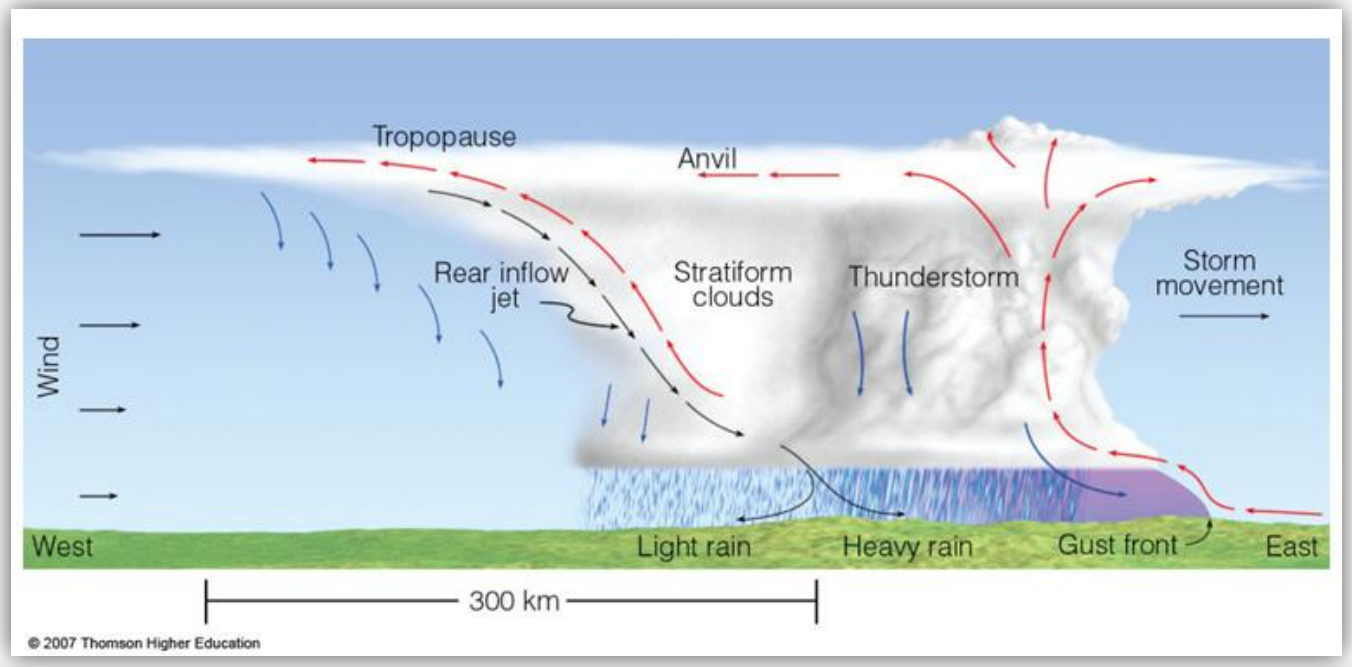
BWER at X Feet Above Ground Level

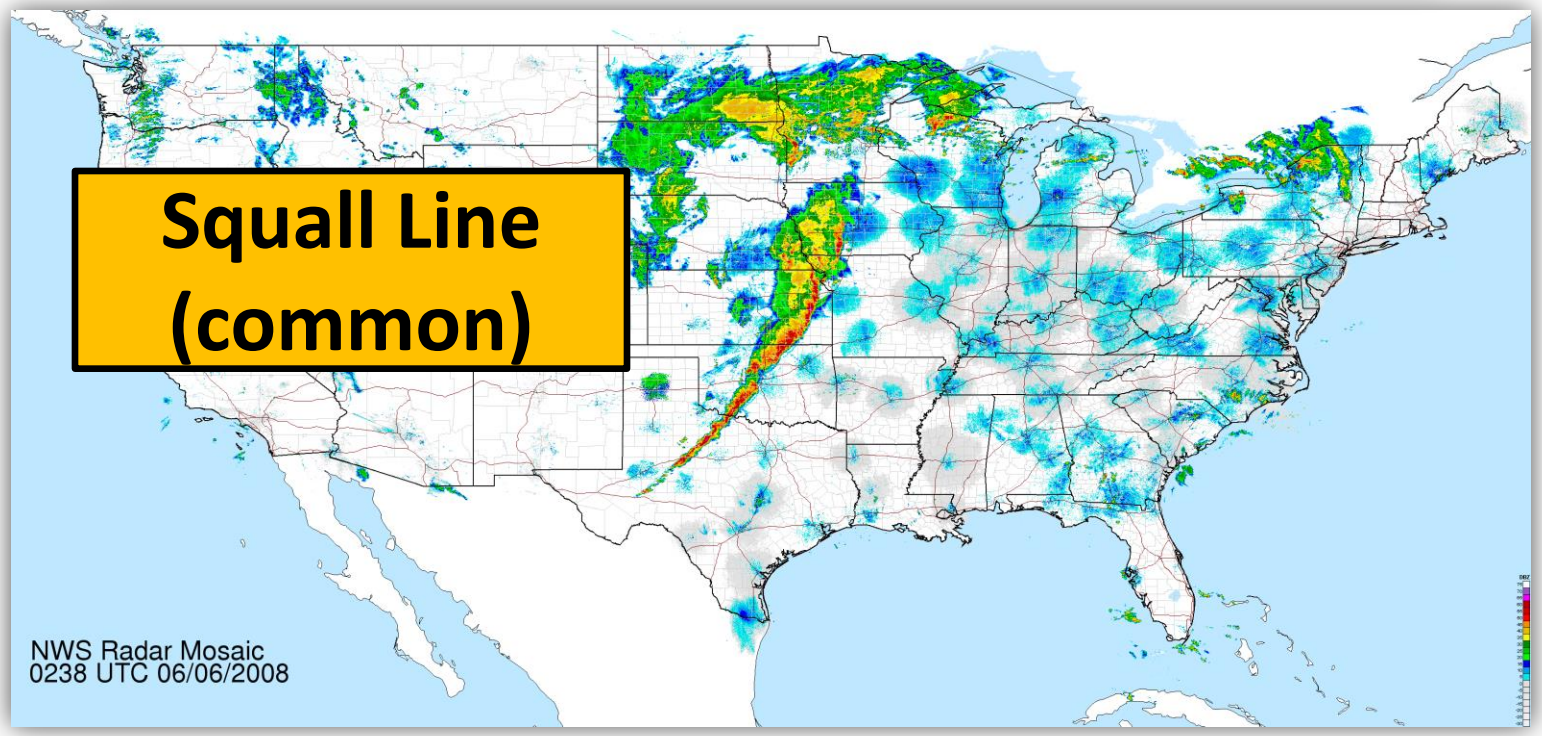




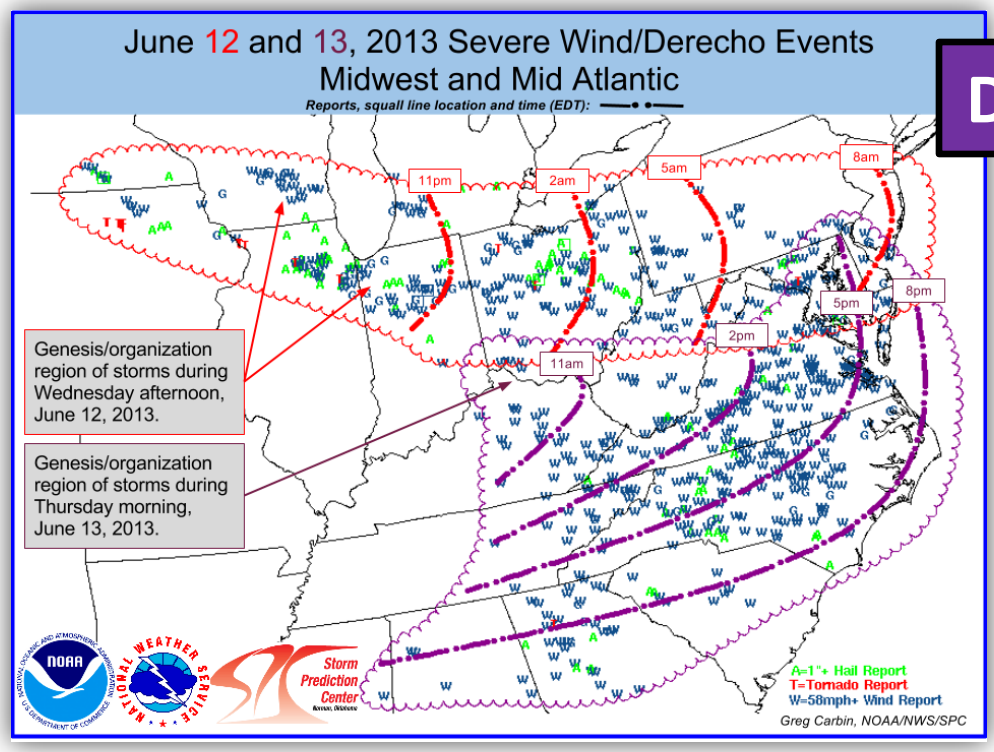


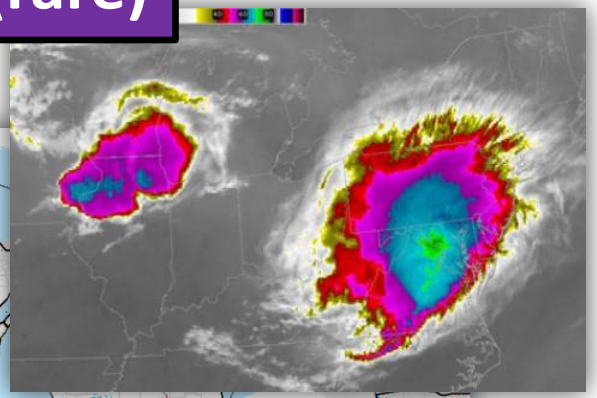


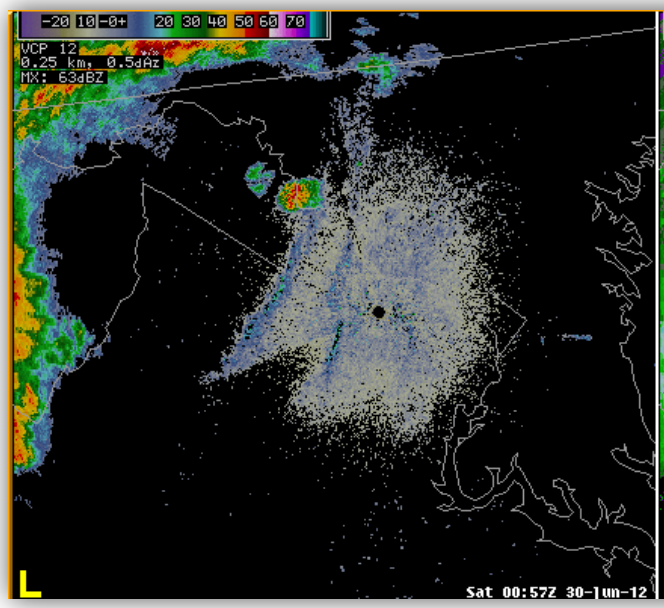

Tropopause
Anvil
Rear inflow jet
Stratiform clouds
Thunderstorm
Storm movement
Wind
West
Light rain
Heavy rain
Gust front
East
300 km
© 2007 Thomson Higher Education

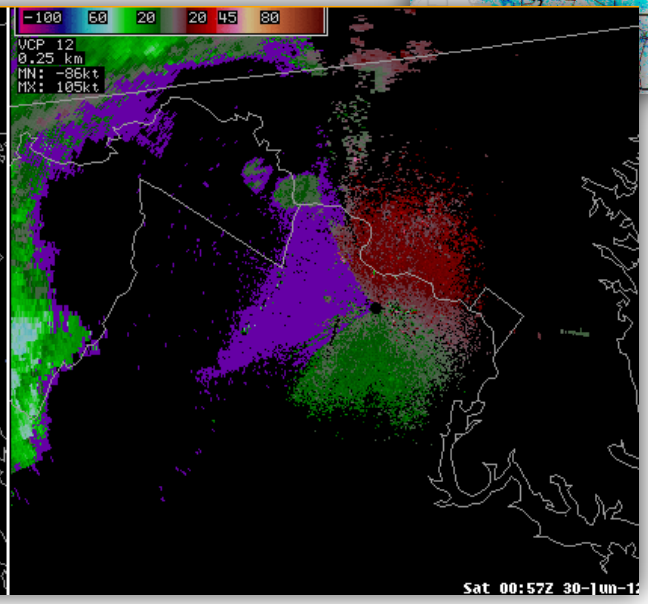

Squall Line (common)
NWS Radar Mosaic
0238 UTC 06/06/2008

Derecho (rare)



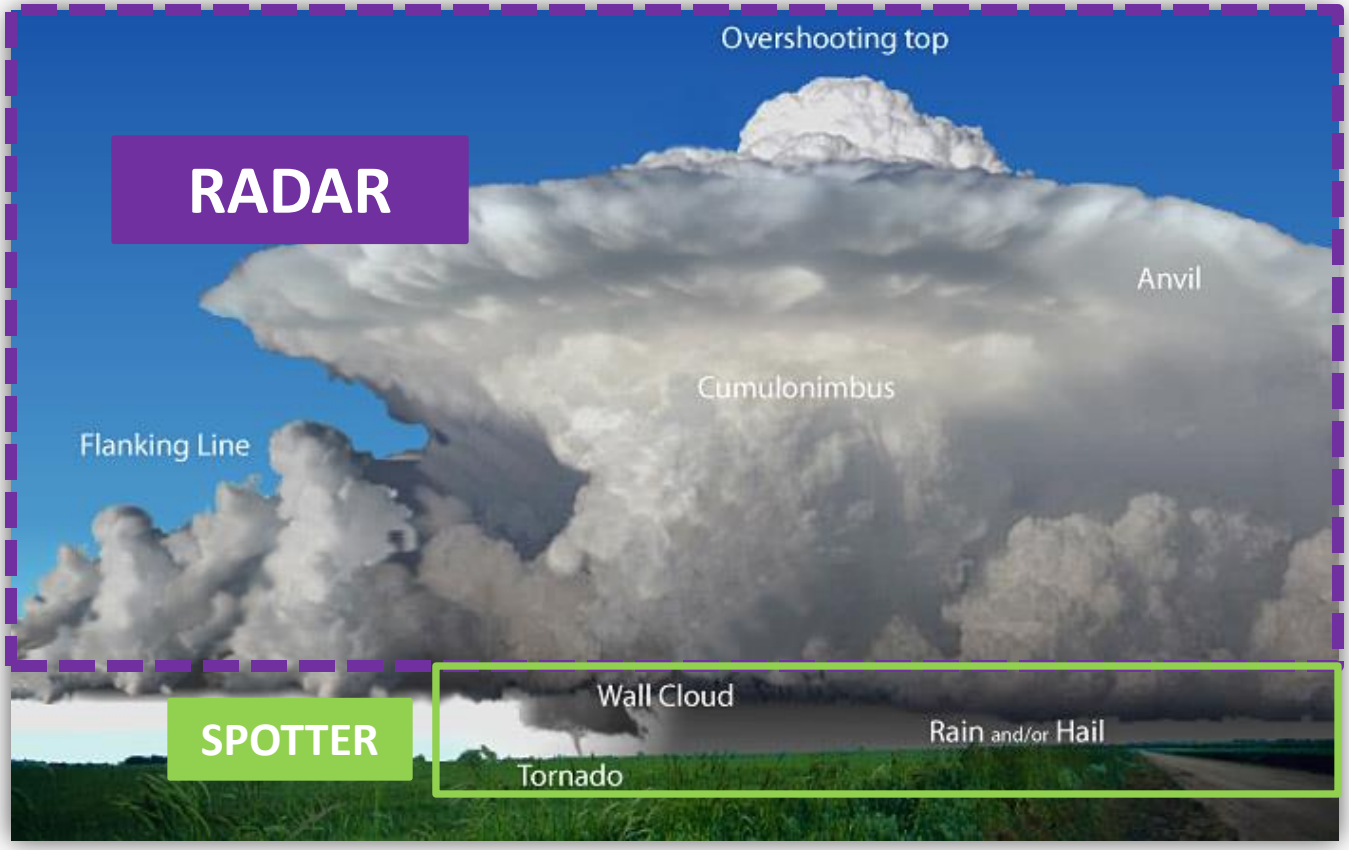






- Damaging winds over swath of 250+ miles
- Concentrated and persistent area of severe winds, damage
- Maintained over 6+ hour duration

Below the Radar Beam? Spotters Help Tell the Story



Radar tells us the storm is capable of producing strong winds, hail, and/or a tornado

Spotters help confirm if the storm is producing damaging winds, hail, and/or a tornado

Important Definitions

OUTLOOK

Anticipated weather hazards during the next 7 days.
Issued daily and updated as needed.
[Keep Tabs] … Ready

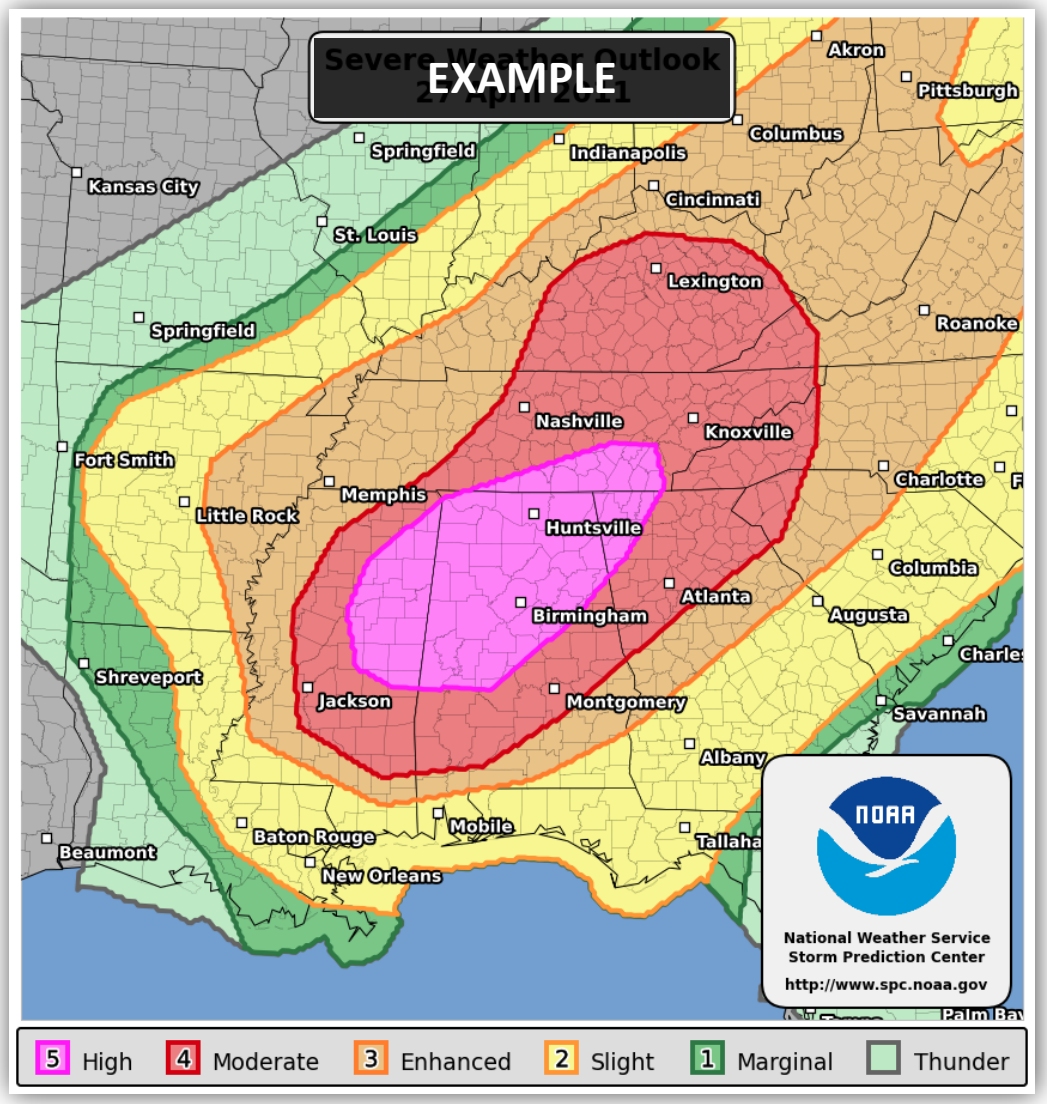
WATCH

Atmospheric conditions are favorable, or could become favorable, for the development of thunderstorms which could produce severe weather.
[Remain Alert] … Set

WARNING

Severe weather is occurring, or is likely to occur.
[Take protective action] … GO!

Storm Prediction Center (SPC) Convective Outlook



Storm Prediction Center Severe Weather Outlook

Understanding Severe Thunderstorm Risk Categories

THUNDERSTORMS (no label)	1 - MARGINAL (MRGL)	2 - SLIGHT (SLGT)	3 - ENHANCED (ENH)	4 - MODERATE (MDT)	5 - HIGH (HIGH)
No severe* thunderstorms expected	**Isolated severe thunderstorms possible**	**Scattered severe storms possible**	**Numerous severe storms possible**	**Widespread severe storms likely**	**Widespread severe storms expected**
Lightning/flooding threats exist with <u>all</u> thunderstorms	Limited in duration and/or coverage and/or intensity	Short-lived and/or not widespread, isolated intense storms possible	More persistent and/or widespread, a few intense	Long-lived, widespread and intense	Long-lived, very widespread and particularly intense
					
• *Winds to 40 mph* • *Small hail*	• *Winds 40-60 mph* • *Hail up to 1”* • *Low tornado risk*	• *One or two tornadoes* • *Reports of strong winds/wind damage* • *Hail ~1”, isolated 2”*	• *A few tornadoes* • *Several reports of wind damage* • *Damaging hail, 1 - 2”*	• *Strong tornadoes* • *Widespread wind damage* • *Destructive hail, 2” +*	• *Tornado outbreak* • *Derecho*

* NWS defines a severe thunderstorm as measured wind gusts to at least 58 mph, and/or hail to at least one inch in diameter, and/or a tornado. All thunderstorm categories imply lightning and the potential for flooding. Categories are also tied to the probability of a severe weather event within 25 miles of your location.

What Makes a Storm Severe?

- Wind gusts of 58 MPH or greater, and/or
- Hail 1 inch or more in diameter

Severe Thunderstorm Warning is issued for potential of this occurring, or if observed

- A tornado also makes a storm severe

Tornado Warning is issued for potential of this occurring, or if observed

Lightning does not make a thunderstorm severe

Reporting Options Recap

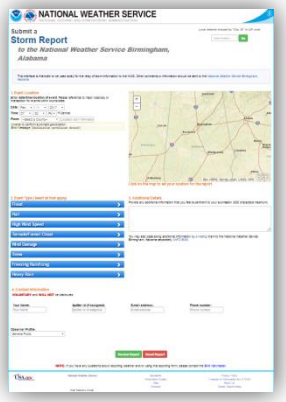
- Call the NWS office: 205-664-3010, option 2
- Social media: Twitter, Facebook
- Our webpage: 'Submit a Storm Report' page
- Photos of what you're seeing/detailed follow-up are great, too!

  SR-BMX.Pix@noaa.gov

  – Snapshot of a funnel, wall cloud, flooding, etc.

  – Hail, wind damage (trees, buildings, etc.)

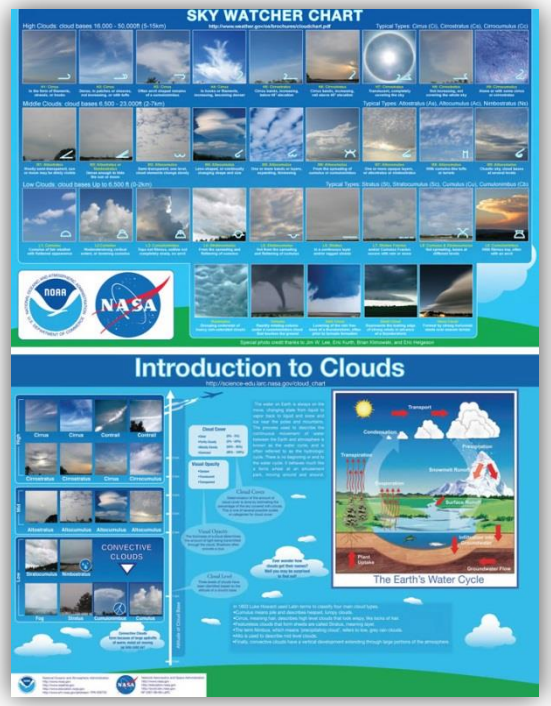
Don't use e-mail for urgent reports!

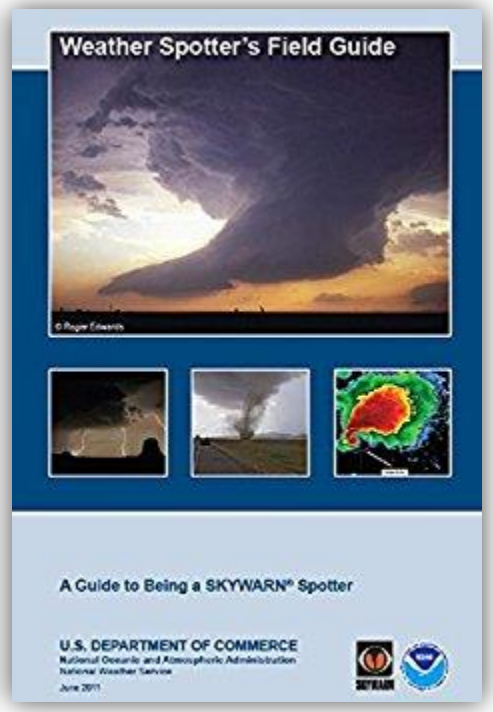


Additional Materials

Visit our Skywarn spotter page for useful links and information: weather.gov/bmx/skywarnschedule

- Advanced spotter certificates
  www.weather.gov/bmx/advancedspottertraining
- Spotter schedule
- Training materials
- Brochures and guides





SKYWARN *Advanced* Training

Gerald Satterwhite
Meteorologist

U.S. Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)
National Weather Service (NWS) – Calera, AL

Questions, Suggestions, or Comments?
Gerald.Satterwhite@noaa.gov

We thank you for your participation!
Keep your eye in the sky!